Water and Environmental Research Institute of the Western Pacific
Annual Technical Report
FY 2012

Introduction

The Water & Environmental Research Institute of the Western Pacific or WERI is one of 54 similar water research institutes set up by U.S. Congressional legislation at each Land Grant University in the United States and in several territories. The Institute is now in its 39th year of operation.

WERI's mission is to seek solutions through research, teaching and outreach programs, to issues and problems associated with the location, production, distribution, and management of freshwater resources. The Institute provides its regional stakeholders with technical expertise in a diversity of water resources related fields including tropical climatology, surface water hydrology, rainfall catchment systems, groundwater modeling and management, water distribution systems, soil erosion and mitigation strategies and various aspects of water quality. Faculty members contribute significantly to both undergraduate and graduate teaching programs at the University of Guam (UOG) and conduct vigorous research aimed at improving economic conditions and the quality of life for citizens of Guam and the regional island nations. WERI also operates a state of the technology water analytical laboratory and geographical information systems analysis and training facility.

WERI administers and carries out research, training, and other information transfer programs under a variety of federal and local funding sources, but the Institute was created specifically to administer Department of Interior funds (via the US Geological Survey) under Section 104-B of the Water Resources Research Act. WERI has responsibility for the administration of three 104-B base grants: one for Guam, one for the Commonwealth of the Northern Mariana Islands (CNMI), and one for the Federated States of Micronesia (FSM). This report summarizes the Institute's regional activities under the USGS 104-B base grant program for the period March 1, 2012 to February 28, 2013 (FY 2012).

Currently WERI has a full-time Director who is also a UOG faculty member, five (5) regular and one (1) emeritus research faculty, a water analysis laboratory manager and technician, one staff hydrologist that administrates the GIS and network system, two office staff, as well as six (6) graduate research assistants who are completing their MS degree in the UOG Environmental Sciences program.

During FY12, WERI faculties were involved as principal investigators on eighteen (18) research and training projects. Funding sources for these projects, in addition to the US Geological Survey, included the National Oceanic and Atmospheric Administration, the National Weather Service, the National Science Foundation and the US Military, and local agencies such as the Guam Bureau of Statistics and Plans, the Guam Environmental Protection Agency, the Guam Waterworks Authority, and direct appropriations from the Guam Legislature.

Over the same time frame, WERI faculty and staff taught fourteen (14) graduate courses and one (1) undergraduate course in the Environmental Science MS program and the undergraduate Pre-Engineering curricula respectively. At the same time WERI faculty were first or second authors on nine (9) refereed journal articles, three (3) conference proceedings papers, two (2) technical reports, seventeen (17) professional presentations, and four (4) workshops. WERI faculty members served on eighteen (18) thesis committees of students in the Environmental Science and Biology MS programs and chaired nine (9) of them.

Following is a list of non USGS funding sources and associated projects carried out by the Institute during the 2012-2013 reporting period:

DIRECT LOCAL FUNDING FROM THE GUAM LEGISLATURE SUPPORTS: A. The Guam Comprehensive Water Monitoring Program, a 50:50 cost sharing program with Hawaii District, USGS B. The Guam Hydrologic Survey, which in turn has provided funding over this fiscal year for the following projects: 1. Guam Geologic Map Update and Revision; 2. Reconstructing the Climate History of Guam; 3. Temporal

and Spatial Variations in Guam's Groundwater Quality.

GUAM BUREAU OF STATISTICS AND PLANS HAS PROVIDED FUNDS TO: 1. Develop the Erosion Potential GIS Based Tool for the Piti/Asan Watershed; 2. Provide GIS Technical Support for GIS Applications for Watershed Management Projects for Guam's Priority Watersheds; 3. Develop Digital Atlas of Northern Guam; 4. Provide GIS Assessment Tool for Determining Cumulative and Secondary Impacts from Increase Development on Guam; 5. GIS Technical Support for GIS Applications Master Planning and Land Use; 6. GIS Application for Wetland Delineation Mapping.

GUAM WATERWORKS AUTHORITY AND NAVFAC MARIANAS HAVE PROVIDED FUNDS TO: 1. Determine if Guam's Northern Aquifer Should be classified as Groundwater under the Direct Influence of Surface Water (GWUDI) in Accordance with the Safe Drinking Water Act, Surface Water Treatment Rule.

NATIONAL SCIENCE FOUNDATION HAS PROVIDED FUNDS TO: 1. Examine the Holocene Hydrologic Variability Across the Western Pacific Warm Pool.

NATIONAL WEATHER SERVICE HAS PROVIDED FUNDS TO: 1. Pacific ENSO Applications Center with University of Hawaii: JIMAR Project, Climate Forecast & Information; 2. Pacific ENSO Applications Center with University of Hawaii: JIMAR Project, Development of an Extended and Long-Range Precipitation System over the Pacific Islands; 3. Pacific ENSO Application Center-NOAA, Department of Commerce; 4. Pacific Island Climate Science Center with University of Hawaii.

Research Program Introduction

The Water and Environmental Research Institute (WERI) Advisory Council is the body, which determines research goals and priorities for WERI in general and the USGS 104B program in particular. The Research Advisory Council (RAC) for Guam consists of representatives from all Guam governmental agencies involved with water resources development or regulation, members of U.S. Federal agencies, military organizations on Guam that deal with water resources issues and members of the university research community. The RAC for the Commonwealth of the Northern Mariana Islands (CNMI) and the Federated States of Micronesia (FSM) consist of representatives from various government departments that deal with water resources, representatives from the local colleges, private sector engineers, environmentalists, and planners, and University of Guam research faculty.

WERI held RAC meetings in September through October 2012. Twenty four (24) people attended the Guam meeting, sixteen (16) attended the FSM meeting and twenty five (25) attended the CNMI meeting. The meetings provided a scientific forum for information exchange on new and recently completed projects. Each RAC group examined the research education and training priorities identified in past years and added or amended where appropriate.

In early November, a Request for Proposals (RFP) letter was sent out by e-mail to over three hundred (300) regional representatives in Guam, the CNMI and FSM. Recipients included all past and present RAC members; faculty members at the University of Guam, the Northern Marianas College in Saipan and the College of Micronesia in Pohnpei, and water resource professionals from several government agencies. Accompanying the RFP message were: a) a blank proposal form for submittal on the USGS Web Site, b) detailed instructions on how to fill out the form, and c) the critical water resource research, education and training needs identified for Guam, the CNMI and FSM.

Seven (7) research proposals, one (1) for Guam, four (4) for the CNMI and two (2) for the FSM; four (4) environmental educational programs, two (2) for Guam, one (1) for the CNMI, one (1) for the FSM; and three (3) information transfer and training programs, one (1) for Guam, and two (2) for the FSM were submitted for consideration in response to the RFP. Three regional review panels, each composed of well qualified water resources professionals and RAC members were tasked with evaluating each proposal's regional relevance in accordance with the long-standing criteria listed in the RFP. The appropriate proposals were e-mailed separately to each reviewer along with the critical needs list for the region and a scoring form. The reviewers were advised to work independently and given two weeks to submit their scores and comments to the WERI Director. The proposal scores were then tabulated and the projects ranked in descending order of average score. Projects approved for funding were selected based on their regional ranking and availability of funds.

USGS Award No. G11AP20225 Hydrogeological Database for Northern Guam

Basic Information

Title:	USGS Award No. G11AP20225 Hydrogeological Database for Northern Guam
Project Number:	2011GU214S
Start Date:	9/1/2011
End Date:	1/31/2013
Funding Source:	Supplemental
Congressional District:	N/A
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Models, Management and Planning
Descriptors:	Aquifer database, boundary conditions, engineering management data
Principal Investigators:	John Jenson

Publications

1. Bendixson, Vivianna, 2011, 3-D Groundwater Database for the Northern Guam Lens Aquifer, American Water Works Association, Hawaii Section 37th Annual Conference, May 5, 2011, Honolulu, Hawaii.
2. Rotzoll, Kolja, Stephen B. Gingerich, John W. Jenson, and Aly I. El-Kadi, 2012, Estimating Hydraulic Properties from Tidal Attenuation in the Northern Guam Lens Aquifer, Territory of Guam, USA, Hydrogeology Journal (in review)

PROJECT SYNOPSIS REPORT

Project Title: Hydrogeological Database for Northern Guam

Problem and Research Objectives
A three-dimensional numerical model of the Northern Guam Lens Aquifer (NGLA) is under joint development by USGS and WERI. A prerequisite to the development of such a model is a comprehensive database containing the data to support not only the model, but also other management and regulatory activities as well. The proposed project will not only continue the development of a three-dimensional (3-D) Geographic Information System (GIS)-based database to support development and operation of the numerical model, but will provide the permanent, central and accessible database and visualization tool for local and federal managers, engineers, water scientists, and regulators working on all aspects of the Northern Guam Lens Aquifer.

Methodology
An online version of the well database for the Northern Guam Lens Aquifer will be developed. The well database includes: well name, well owner, location (WGS84 coordinate system), land surface elevation, casing and hole diameters, well depth, solid casing length, depth to volcanic basement rock, year drilled, permitted yield, pumping records, water level records, chloride records, drill logs, and aquifer-test data. The database is comprised of Excel spreadsheets and PDFs of all source documents. The scope of work will involve documenting and publishing the well database using ArcGIS Online. Data layers will include: (1) point coverage and attribute table for all wells in the database, (2) map of contours showing the depth to volcanic basement rock, and (3) point coverage and attribute table for wells used to develop the map of contours showing the depth to volcanic basement rock.

Principal Findings and Significance
The proposed project continues ongoing research and development to provide the essential database for development of a numerical model of the NGLA. The ultimate result, however, including the application of the numerical model, will be to support the long-term sustainable management of the water supply of northern Guam. The database will provide the platform for tracking and making available the indicators of status and trends in water availability based on hydrologic data collected by the USGS and others. The dynamic model and the supporting GIS database will also be important tools for evaluating management options for preserving or enhancing water availability under drought or flood conditions, as well as characterizing and quantifying components of the water cycle. Specific applications of these tools will be to assess the effects of water regulation and institutional arrangements on availability of water for alternative uses and the effectiveness of Best Management Practices (BMPs) in sustaining urban and rural raw water supply quality. Additionally, they will provide essential tools for cooperative, inter-agency management. Finally, they will help provide for effective water management to support rapid development anticipated by the planned military build-up on Guam to preclude potential conflicts over water supply.

Spatial and Temporal Analyses of the Relationship Between Groundwater Salinity and Rainfall Amounts, Timing, and Intensity in the Northern Guam Lens Aquifer

Basic Information

Title:	Spatial and Temporal Analyses of the Relationship Between Groundwater Salinity and Rainfall Amounts, Timing, and Intensity in the Northern Guam Lens Aquifer
Project Number:	2012GU218B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	N/A
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Hydrology, Hydrogeochemistry
Descriptors:	Saltwater contamination, salinity trends, Guam
Principal Investigators:	John Jenson, Mark Lander

Publications

1. Simard, Christine A., John W. Jenson and Mark A. Lander, 2013, in review, Analysis of Salinity in the Northern Guam Lens Aquifer, 6th Symposium on the Geology of the Bahamas and Similar Regions, Gerace Research Center, San Salvador Island, Bahamas.
2. Simard, Christine A., John W. Jenson, and Mark A. Lander, 2012, Analysis of Salinity in the Northern Guam Lens Aquifer, 16th Symposium on the Geology of the Bahamas and Similar Carbonate Regions, Gerace Research Center, San Salvador Island, Bahamas.
3. Simard, Christine A., 2012, Salinity Trends in the Northern Guam Lens Aquifer, M.S. Thesis, Graduate Environmental Science Program, College of Natural and Applied Sciences, University of Guam, Mangilao, Guam, pp. 281.

PROJECT SYNOPSIS REPORT

Project Title: Spatial and Temporal Analyses of the Relationship between Groundwater Salinity and Rainfall Amounts, Timing, and Intensity in the Northern Guam Lens Aquifer

Problem and Research Objectives

The Northern Guam Lens Aquifer (NGLA) provides 80% of Guam's drinking water. Total withdrawal by all producers is currently about 45 million gallons per day (mgd), against a currently estimated sustainable yield of about 80 mgd. The anticipated military buildup during the next decade is expected to require an additional 5-6 mgd of drinking water to support the new military activities alone, and additional economic growth on the island will certainly further increase demand for municipal and private production as well. Recent study of the temporal trends in salinity show long-term increases in most wells and substantial increases since 2006 at some wells. The reason for the observed increases in the salinity of wells tapping the NGLA is not know. It may be the result of changes in pumping volume and pumping distribution across the aquifer, or changes in the character of Guam's rainfall, which has undergone substantial changes across the decades of the 1990s into the 2000s. There have also been some dramatic changes in Guam's climate during the past two decades (air and sea temperature rise, substantial – 12 cm – sea level rise, and abrupt changes to the typhoon distribution). It is possible that these climatic changes (whether temporary or permanent) are having (or will have) effects (possibly adverse) to the quantity and quality of the water in the NGLA.

Methodology

Salinity trends in Guam's production wells show substantial cycles in salinity that cannot be explained by anthropogenic factors, and suggests that long-term trends in aquifer salinity may be affected by natural factors in addition to human factors. Moreover, an ongoing study of the chemistry of locally-collected rainwater versus percolating groundwaters suggests that recharge may come almost exclusively from rainfall that arrives in the five wettest months of July through November. Together, these results point to the need for continued and more tightly focused study of the relationship between the meteorological and hydrogeological processes that affects the spatial distributions and the amounts, timing, rates, and quality of waters traveling from the ground surface to water-table surface. This project built on previous and ongoing related work to compile and evaluate historical and current WERI/USGS data collected through ongoing programs. Data are now being compiled into a comprehensive database.

Principal Findings and Significance

The results of the proposed project will provide Guam's civilian and military water resources managers and regulators with:

(1) Better understanding of the natural mechanisms that control or influence the salinity of groundwater in Guam's carbonate island karst aquifer
(2) Essential knowledge by which to separate the natural from the human-induced changes in groundwater salinity, and greater confidence in developing and revising sustainable management criteria for Guam's groundwater resources.

LiDAR-based Delineation and Hydrologic Modeling of Southern and Central Guam Watersheds

Basic Information

Title:	LiDAR-based Delineation and Hydrologic Modeling of Southern and Central Guam Watersheds
Project Number:	2012GU219B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	N/A
Research Category:	Climate and Hydrologic Processes
Focus Category:	Management and Planning, Surface Water, Hydrology
Descriptors:	Watershed boundaries, drainages, surface water flow, watershed management, hydrology, Southern Guam, LiDAR
Principal Investigators:	Maria Kottermair

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

Project Title: LiDAR-based Delineation and Hydrologic Modeling of Southern and Central Guam Watersheds

Problem and Research Objectives

Watersheds as hydrologic units define geographic boundaries used for natural resource management and for hydrologic and related modeling. A "ridge-to-reef" (watershed-based) approach to management of natural resources, especially freshwater resources, has been promoted since the establishment of the Clean Water Action Plan (CWAP) for Guam - Unified Watershed Assessment in 1998. The CWAP includes a watershed map and a list of all watersheds categorized by need for restoration. Northern Guam, which comprises of a single limestone plateau with no defined surface flow, is considered one watershed, whereas Southern and Central Guam is divided into 19 watersheds according to a NRCS classification outlined in the CWAP. At the same time, the Northern Guam, Ugum, Talofofo, and Piti-Asan watersheds have been identified as priority watersheds. The major problem identified as affecting water quality is erosion and ensuing sedimentation. Over the past decade, considerable efforts have been made through erosion modeling and actual restoration projects. These activities are on-going and aim to improve water quality in priority watersheds as well as the others watersheds. Concurrently, the Advisory Council Meetings of the Water and Environmental Research Institute of the Western Pacific (WERI) has identified a number of water resource projects of critical need over the past years. Many of these projects focus on surface water quality and quantity and are also watershed-based. To be successful, these projects require precise delineation of the watersheds and other accurate geospatial information. The modeling of fresh water resources is nowadays usually done entirely or at least partly using a geographic information system (GIS).

Currently, two data sets outlining watershed boundaries are available in GIS format. One is based on USGS topographic maps, the other one on a 10-meter by 10-meter resolution digital elevation model (DEM). In 2007, the Government of Guam acquired high-resolution Light Detection and Ranging (LiDAR) data for the entire island of Guam. Few watersheds and drainage basins have been delineated using LiDAR data, but only on a project by project basis. No attempts have been made to update all of Guam's watershed and sub-watershed boundaries using LiDAR despite the need to have more accurate boundaries that are also consistent with other LiDAR-derived data such as slope or a relief. No attempts have been made to update all of Guam's watershed and sub-watershed boundaries using LiDAR despite the need to have more accurate boundaries that are also consistent with other LiDAR-derived data such as slope or a relief.

This project produced a comprehensive hydrologic GIS model that includes watershed characteristics such as watershed and sub-watershed boundaries, rivers, and flow direction and accumulation in addition to terrain characteristics such as slope and aspect, all based on 2007 LiDAR data. Such high-resolution and up-to-date geospatial information will become a vital resource for researchers, managers, technical staff and others. Its availability is especially timely considering that the demand for updated and

comprehensive GIS data has been on unprecedented increase since the Government of Guam acquired an ArcGIS enterprise license. All government agencies, including the University of Guam, now have unlimited access to GIS software and rely on it for nearly all geospatial planning, development, modeling, management, and research applications.

Methodology

This project was performed using the ArcGIS 10 software and the extension ArcHydro, a specific program applied worldwide for hydrologic modeling. The work was based on a 2-meter by 2-meter digital elevation model (DEM) derived from 2007 LiDAR data. Due to the vast volume of data, the DEM had to be divided into three areas prior to processing. The DEM needed to be pre-processed to ensure accurate hydrologic modeling to derive flowlines and watersheds. The pre-processing included DEM reconditioning, which fills artificial depressions and sinks and breaches artificial barriers such as roads to ensure an unobstructed surface flow, producing what is known as a hydrologically connected DEM (Figure 1). The DEM reconditioning is a tedious and time-consuming step as it required several iterations of tools in addition to visual inspection and manipulation. The general workflow to breach artificial barriers was based on Poppenga *et al.* (2010) and Ducey *et al.* (2012). In order to minimize the step repetition, ModelBuilder (a tool in ArcGIS) was utilized to automate the individual steps. For more information on the parameters used, please contact the author directly. Whenever feasible, field investigation was conducted for verification.

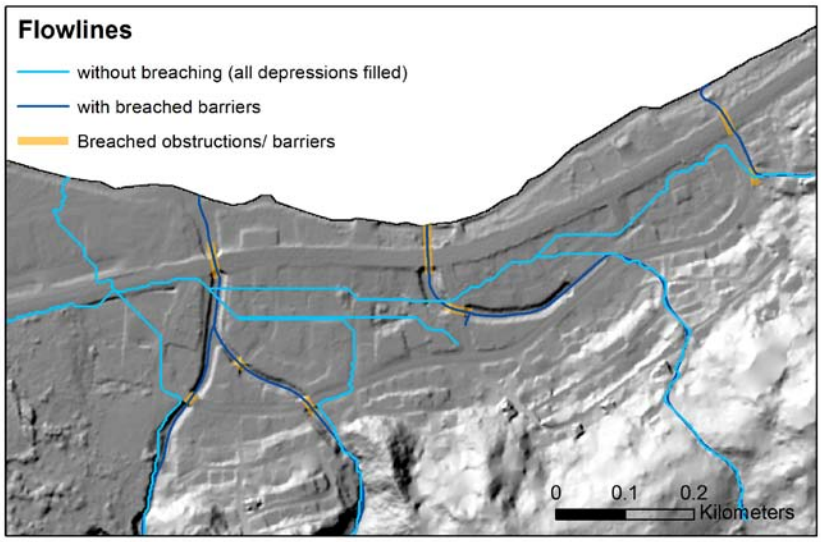

Figure 1. *Example of flowlines derived from a hydrologically connected digital elevation model (DEM) with all depressions filled (light blue line) versus a DEM with artificial barriers breached (dark blue line) resulting in flowlines following its natural course.*

Following DEM reconditioning, the ArcHydro model, which includes flow direction and accumulation, stream delineation, and drainage delineation, was applied and produced raster and vector datasets as output. Certain vector datasets, such as rivers, were smoothed to ensure a more visually appealing line while remaining geographically correct. Characteristics such as geometry (area or length) and names were added to each

watershed, sub-watershed (where applicable), and river feature class. Metadata following FGDC standard were added to all files. The datasets are packaged into a complete geodatabase for public distribution, but are also available to end users as partial sets of files, thus allowing interested individuals to access to full scope of data or single feature class such as rivers as per specific needs.

Principal Findings and Significance

The result of this project is an updated and comprehensive hydrological GIS dataset (raster and vector GIS data) of Southern and Central Guam. The dataset includes stream and river delineation, flow direction, flow accumulation, drainage areas, and watershed boundaries (Figure 2 and 3). All datasets may be used as base data for other hydrologic modeling (*e.g.*, contaminant flow, USLE) and as geographical boundaries for management purposes in conservation efforts. A typical example of an application of the proposed dataset for natural resource managers or technical staff (*e.g.*, Guam EPA Water Monitoring Program) would be locating the potentially affected area of a sewage spill or other contaminant spill. Another common example where these data would be highly valuable is high-resolution tracing of contaminant from a known point-source.

The datasets created for this project are directly distributed to the main entities working on watershed-based projects on Guam. The utilization of this new dataset as a widely-available standard with uniform boundaries and names will ensure consistency within and across projects and activities carried out by different entities and for a variety of purposes. A manual describing each dataset and its use has also been developed and will soon be available. A half-day workshop for government agencies and other interested parties working on watershed management and surface water monitoring will be conducted in the near future.

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In addition to direct distribution to major stakeholders, the data and manual produced over the course of this project will be incorporated into the digital Natural Resources Atlas of Southern Guam (available at www.hydroguam.net). The atlas is widely used by various entities including schools, researchers, and government agencies as a reference and didactic tool about Guam's natural resources. Users of this website will have the ability to download the GIS data produced by this project, adding an educational and public awareness component to this work.

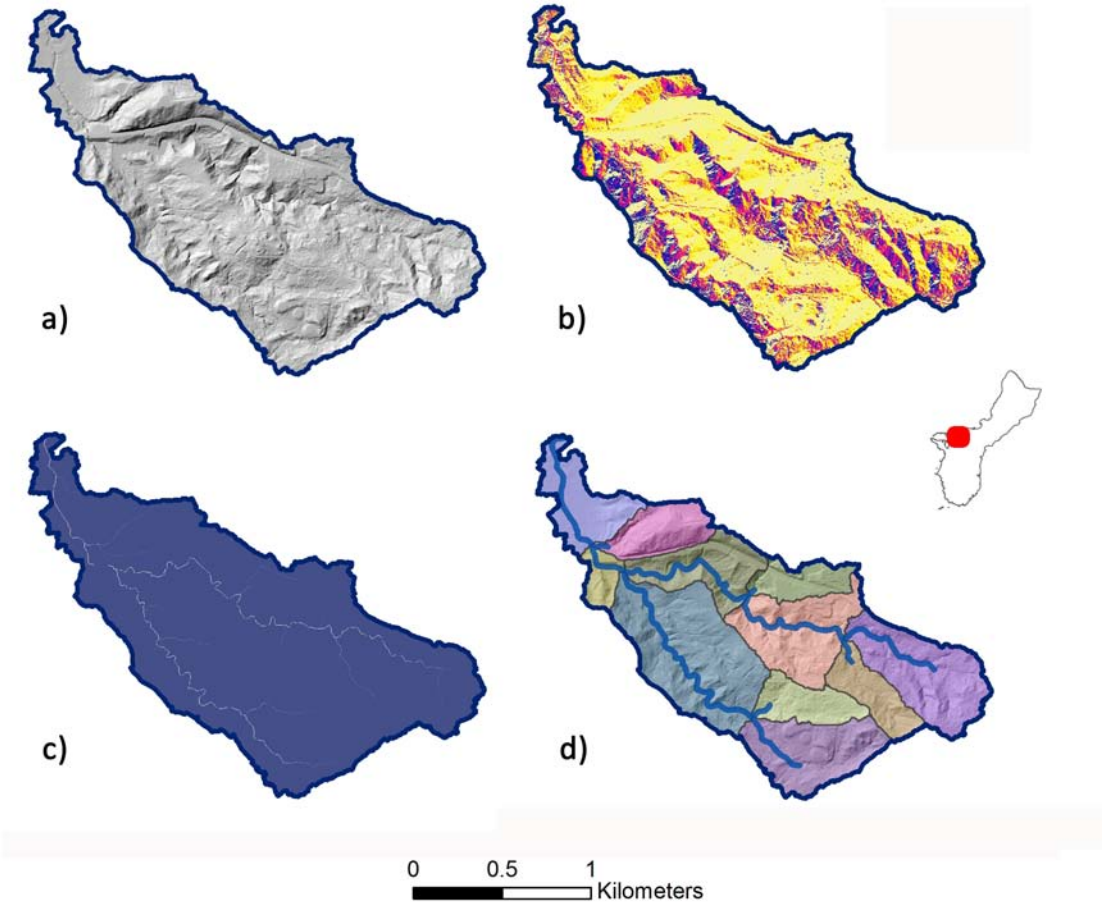

Figure 2. *Example of the hydrologic datasets derived in this project; a) hydrologically connected digital elevation model, b) flow direction raster, c) flow accumulation raster, and d) flowlines (rivers) and drainage boundaries of the Masso watershed.*

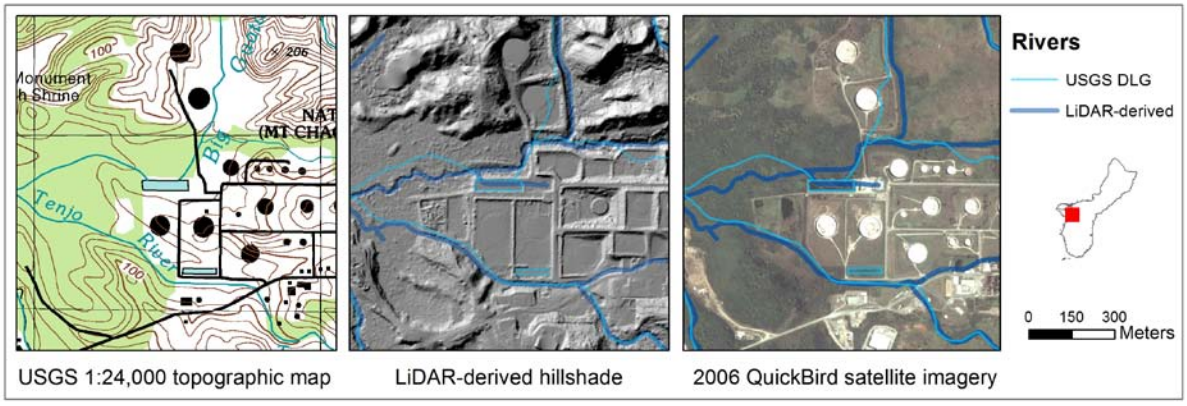

Figure 3*. Comparison of the river digital line graphs from the USGS 1:24,000 topographic maps and the newly derived rivers based on high-resolution LiDAR-derived digital elevation models.*

Finally, and highly significantly, the created watershed and river datasets will provide high-resolution base data for the first detailed National Hydrography Dataset and Watershed Boundary Dataset (NHD/WBD) for Guam. These datasets will be available for viewing and download, upon completion of the NHD/WBD project and official reviews of the respective committees (Spring 2014), as part of the USGS official National Map (http://nationalmap.gov/). It will be the first U.S. federal unit (state or territory) to have flowlines and watershed boundaries derived entirely from LiDAR data instead of USGS 1:24,000 topographic maps or lower-resolution digital elevation models. Since the NHD/WBD project involves a rigorous review of any changes (*e.g.*, outline or name) to the current official watershed boundaries, the naming of the watersheds and combining of smaller watersheds into formally recognized watersheds are presently in draft form only and are not yet publicly distributed, though available upon request from the author.

References Cited

Ducey, C., Wickwire, D., and Stevens, J. 2012. A Proposed Workflow for Delineating Stream Networks from Lidar-Derived Digital Elevation models to Update the National Hydrography Dataset (NHD) in the Pacific Northwest. *In* Proceedings of the Geographic Information Systems and Water Resources VII – AWRA Spring Specialty Conference. New Orleans, Louisiana.

Poppenga, S.K., Worstell, B.B., Stoker, J.M., and S.K. Greenlee, 2010. Using Selective Drainage Methods to Extract Continuous Surface Flow from 1-meter Lidar-derived Digital Elevation Data: US Geological Survey Scientific Investigations Report 2010-5059, 12 p.

Development of Water Usage Pattern (Diurnal Demand Pattern) for Saipan Water Distribution System

Basic Information

Title:	Development of Water Usage Pattern (Diurnal Demand Pattern) for Saipan Water Distribution System
Project Number:	2012GU221B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	N/A
Research Category:	Engineering
Focus Category:	Models, Water Supply, Management and Planning
Descriptors:	Water use data, Water demands, Distribution system, Model studies
Principal Investigators:	Shahram Khosrowpanah

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

Project Title: Development of Water Usage Pattern (Diurnal Demand Pattern) for Saipan Water Distribution System

Problem and Research Objectives

The Saipan water distribution system has been divided into 15 sub-regions. Each region is expected to operate somewhat independently. However, due to inadequate inflow to some of the sub-regions, system leakage, and lack of knowledge of the system behavior as a whole, the system is unable to provide 24-hour water service. A stated goal of the Commonwealth of the Northern Mariana Islands (CNMI) Government is to provide 24-hour water to all residents served by the Commonwealth Utilities Corporation (CUC) water system. To assist in reaching their goals, the CUC commissioned the University of Guam Water and Environmental Research Institute of the Western Pacific (WERI) to develop a hydraulic model of the Saipan Water System and to train CUC water division staff in the use of that model.

Researchers at (WERI) developed computerized models of each of the fifteen sub-regions of the CUC water system using the Haestad WaterCAD water system modeling program. Later on, they developed a source, transmission and storage model of the Saipan water system. This includes a skeleton of the existing 15-region water system models that are joined together at the boundary points. Using Geographic Information System (GIS) capability and Saipan's 2003 census data the WERI researchers determined the number of users at each system junction node for residential and commercial customers (Heitz, Khosrowpanah 2008) as shown in Figures 1 and 2.

The next step was to better refine estimates of both the quantities and spatial distribution of water demands and how this demand changes with both residential and commercial customers during a period of time. With this information the CUC will be able to improve the operation of the water delivery system, to reduce the maintenance cost, to reduce the amount of the water that is being lost through the system, and ultimately, to improve the system operation for providing 24-hour water to its customers. The objectives of this project were to; 1) determine the average use rate for residential customers in Saipan, 2) develop Diurnal demand pattern (changes of water demand during the day and month) for residential and commercial customers and, 3) export the data developed in step 1 and 2 into the Saipan Water System hydraulic Model, and run the model in extended period simulation mode.

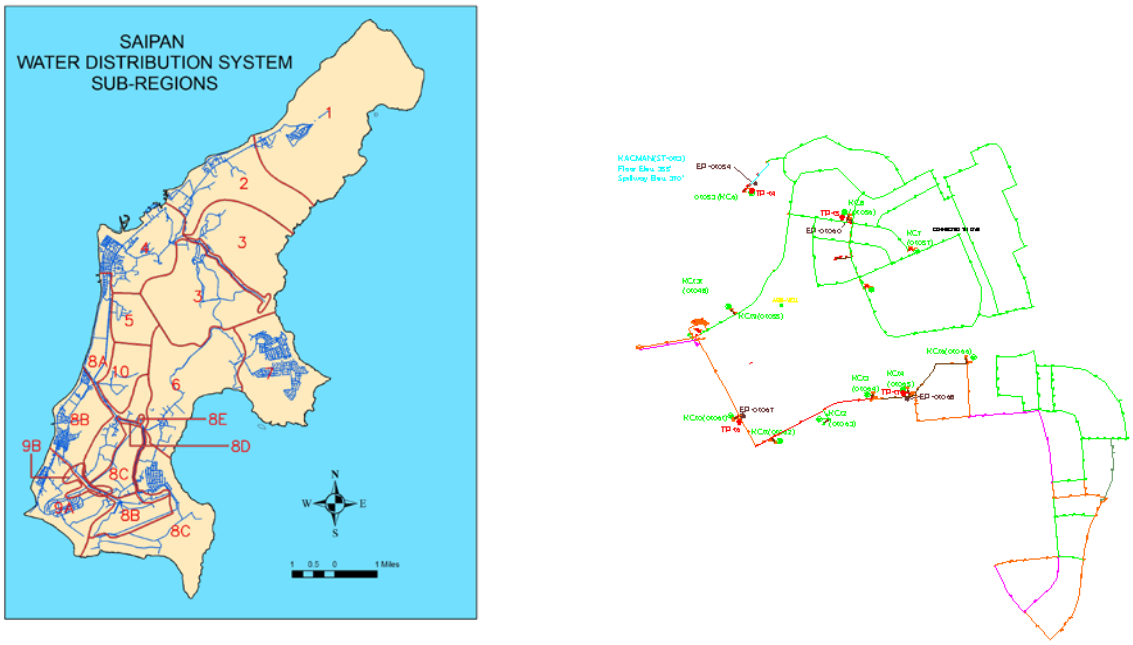

Figure 1. Saipan water distribution system and skeleton model of sub-region 7

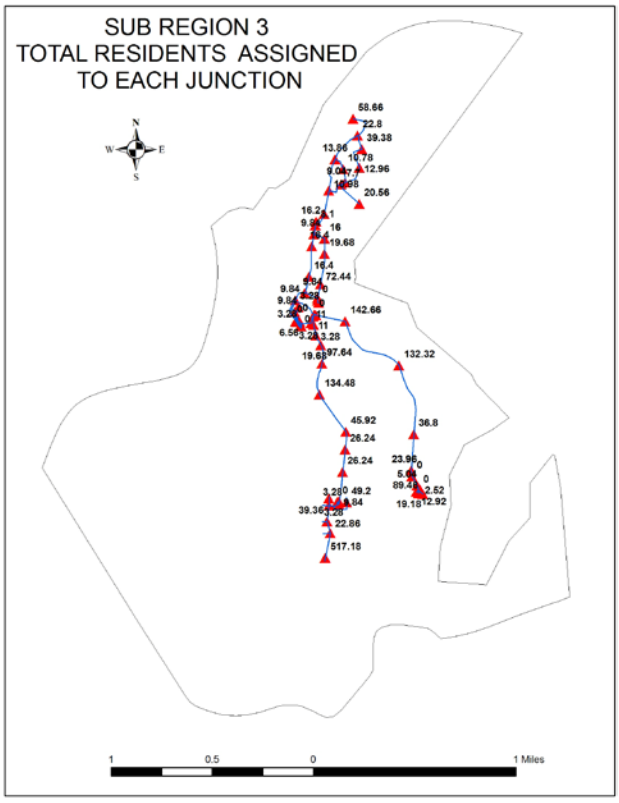

Figure 2. Sub-Region 3 Junctions Labeled With Number of People Assigned to Each Junction

Methodology

The steps that were taken to complete the goals of this project were to: collect hourly, daily, and monthly data from CUC's water meters, develop water demand patterns for residential and selected business, and import the data into hydraulic model. However, we encountered several obstacles that delayed data collection.

1. The water meters that CUC installed (Smart Meter SM700) for all their customers were encoded types (not pulse type) so they couldn't record the hourly water use.
2. We purchased mini-loggers from an Australian distributor for recording the hourly water use. They were not compatible with the CUC's SM700 water meters.
3. Finally we borrowed Metron Farnier meters from Guam Water Works Authority that were able to record hourly water use as shown in figure 3.

The Metron Farnier meter consists of the meter that tracks of water usage and the data logger that tracks of date and time (one hour increment) and stores the water usage. The reader is Palm® PDA (Personal Digital Assistant) that communicates with the logger and extracts the data. We installed five Metron Farnier meters in Kagman – region 7 residential area that has 24-hour water service as shown in Figure 3. Location of the meters is shown in figure 4. Meters were installed in December 20, 2012 and a monthly data collection is continuing until adequate results are obtained. A sample of meter output reading is shown in Figure 5.

Metron Farnier Meter Meter Installation

Figure 3. Metron Farnier meter installation

Meters Installed

No.	Meter Serial Number	Meter Number	Meter Mfg.	Meter Size	Reading Type	Meter Type	Unit of Measure	Date Installed	Begin Reading
1	G05-105091	5528	Farnier	5/8" - 3/4"	Normal	Water	Gallons	12/20/2012	142900
2	G05-089909	5384	Farnier	5/8" - 3/4"	Normal	Water	Gallons	12/20/2012	182200
3	G05-105756	2811	Farnier	5/8" - 3/4"	Normal	Water	Gallons	12/20/2012	3700
4	G05-094406	3359	Farnier	5/8" - 3/4"	Normal	Water	Gallons	12/20/2012	159400
5	G05-055230	9805	Farnier	5/8" - 3/4"	Normal	Water	Gallons	12/20/2012	58200

Meters Coordinate

No.	Customer	Household Size	North	East
1	L. Pangelinan	5	15° 10´ 47.384	145° 46´ 32.411
2	A. Celis	5	15° 10´ 49.122	145° 46´ 35.969
3	T. Towai	8	15° 10´ 36.083	145° 46´ 33.187
4	E. Muna	4	15° 10´ 34.806	145° 46´ 30.095
5	C. Salas	2	15° 10´ 37.030	145° 46´ 30.713

Figure 4. Meter's location

Account Description		Date and Time	Consumption
		12/20/12 1:00	0
Meter ID	9805	12/20/12 2:00	0
Meter Units	gal	12/20/12 3:00	0
Meter Size	3/4"	12/20/12 4:00	0
Meter Type	SJ	12/20/12 5:00	0
Reading Date & Time	12/21/2012 0:00	12/20/12 6:00	0
Encoder Value	10	12/20/12 7:00	0
Pulse Value	10	12/20/12 8:00	0
Raw Reading		12/20/12 9:00	0
Transmit Scaling	0.01	12/20/12 10:00	0
Meter Reading	202.3	12/20/12 11:00	0
Log Interval	60	12/20/12 12:00	0
Radio Type	M1B	12/20/12 13:00	0
Id Type	user	12/20/12 14:00	0
Input Type	ECR-type Encoder	12/20/12 15:00	0
Conservation Days	15	12/20/12 16:00	0
		12/20/12 17:00	0
		12/20/12 18:00	0
		12/20/12 19:00	100
		12/20/12 20:00	200
		12/20/12 21:00	0
		12/20/12 22:00	0
		12/20/12 23:00	0
		12/21/12 0:00	0

Figure 5. Sample meter reading output for meter #3359

Principal Findings and Significance

The Metron meters were installed on 12/20/2012, the first reading was done on 2/9/2013 and the second reading completed on 4/26/2013. Figure 6 shows the average daily water use for the first reading period and Figure 7 is daily water use from 2/9/2013 until the last reading on 4/26/2013. According to these figures the daily water use does not change significantly with the exception of holidays and the weekends which are expected.

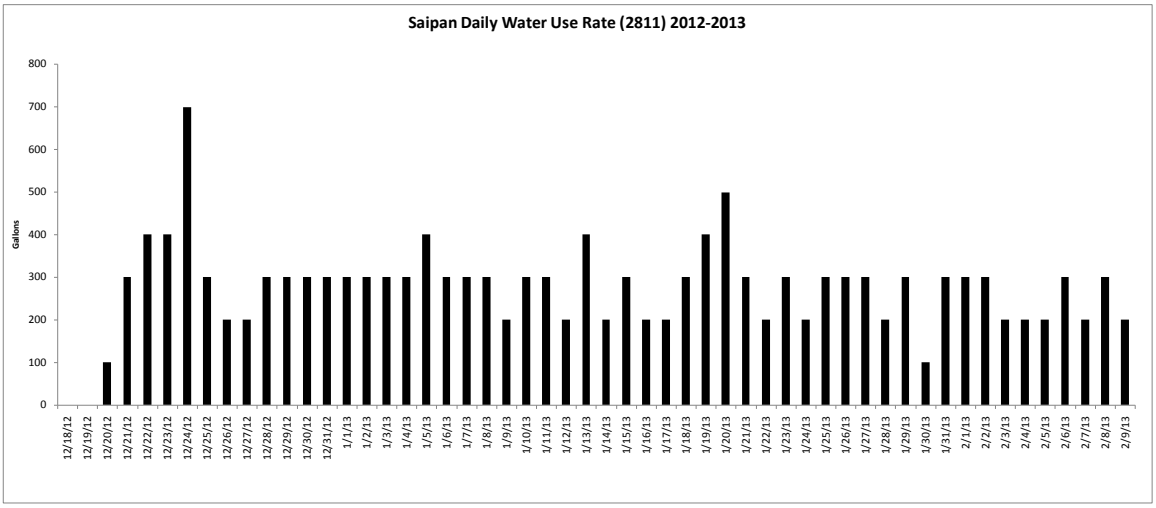

Figure 6. Typical daily water use from 12/20/2012 – 2/9/2013

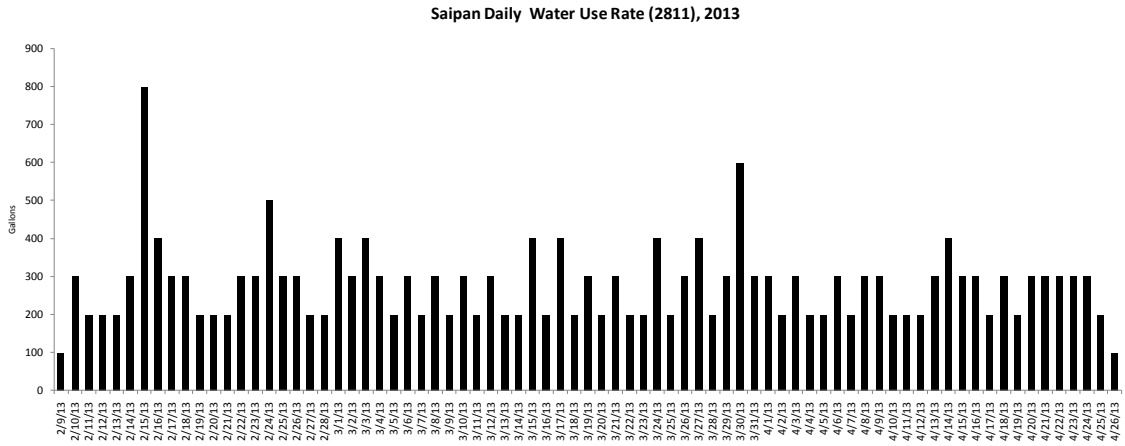

Figure 7. Typical daily water use from 2/9/2013 – 4/26/2013

From the collected data for all the five Metron meters we developed average hourly water use. Since the meter for every 100 gallons water use sends pulse signal to the loggers, we made an assumption that during the 100 gallons water use, the water use stays the same within that period of time. We used 129 days of the one minute's water use data to develop the average hourly water use for a period of 24 hours. Figure 8 shows the residential diurnal water use pattern for Saipan's residential customers. The water use

from 1 am to 7 am stays the same and from 9am it increases until 8pm. Then the water use reduces.

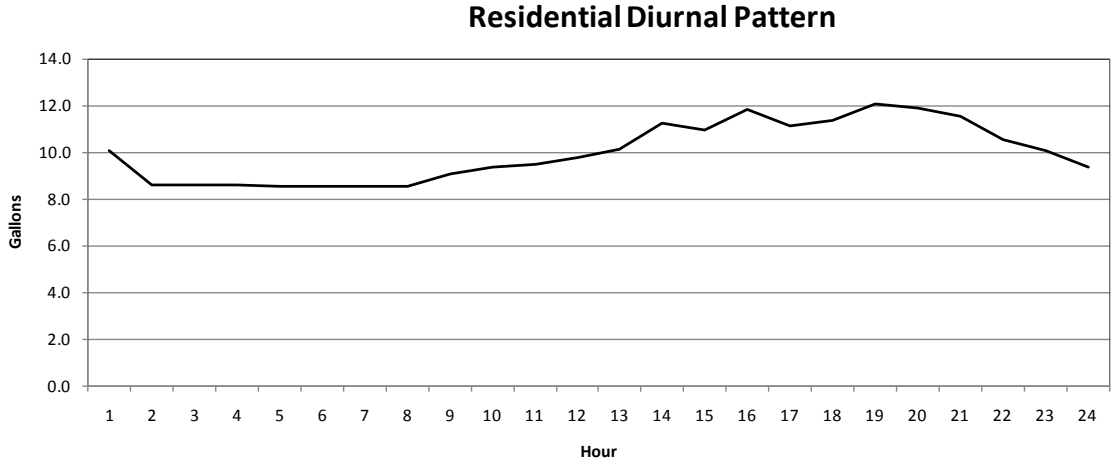

Figure 8. Residential water use pattern for typical Saipan residential customer

Table 1 show the 24-hourly water use. To get a better understanding of the hourly water use, we used four time periods of the water use, 1am – 6am, 7am-12noon, 1pm-6pm, and 7pm to midnight. The results verify the water use patter. The water usage doesn't change, most water use is uniform from 1 am to noon and then increases from 1pm to 6pm. We are using the hourly water use to run the Saipan's water system model in extended period simulation. The developed hourly and daily water use pattern will assist the CUC to: improve the operation of the water system, reduce the system leaks, and improve the operation of the wastewater treatment.

Logger Information		Time (Hour)	Gallon	Average Flow
Meter ID	2811	1	10.05	0.02
Reading Date	12/18/2012	2	8.63	0.13
End Reading Date	4/26/2013	3	8.58	0.28
Total Hours	3,109	4	8.58	0.33
Total Days	129	5	8.56	0.13
Total Gallon	32000	6	8.55	0.33
		7	8.55	0.42
		8	8.55	1.67
		9	9.05	0.24
		10	9.37	0.14
		11	9.45	0.28
		12	9.79	0.42
		13	10.15	3.33
		14	11.26	0.24
		15	10.97	0.42
		16	11.79	0.33
		17	11.13	0.56
		18	11.33	0.42
		19	12.05	0.15
		20	11.87	0.24
		21	11.53	0.33
		22	10.54	0.08
		23	10.09	0.33
		0	9.36	0.12

Period Time	Average Gallons	Average GPM	Period Fraction
1 am to 6 am	52.95	0.15	0.22
7 am to 12 noon	54.76	0.15	0.23
1 pm to 6 pm	66.62	0.19	0.28
7 pm to 12 am	65.43	0.18	0.27
sum	239.77		1.00

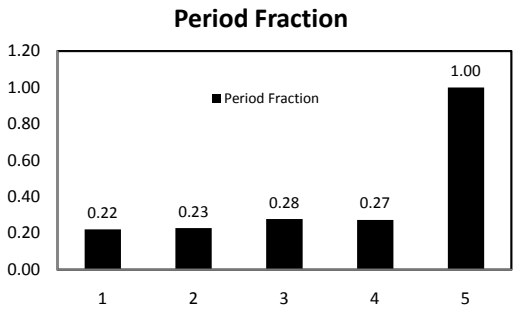

Table 1. Hourly residential water use

Literature Cited

Heitz, F. Leroy, Shahram Khosrowpanah, 2011, Development of a Geographic Information System for the Commonwealth Utility Corporation, Saipan, Water Distribution System, Water and Environmental Research Institute (WERI), University of Guam, Mangilao, Guam, Report No. 132, 17 pp.

Heitz, F. Leroy, Shahram Khosrowpanah, 2008, Development of Junction Water Demands for the Saipan Water Distribution System Numerical Model, Water and Environmental Research Institute (WERI), University of Guam, Mangilao, Guam, Report No. 122, 37pp.

Environmental Impact of FUDS and Brownfields Sites in Watersheds on the Eastern Side of Saipan: Phase 2. Impact on Aquatic Resources

Basic Information

Title:	Environmental Impact of FUDS and Brownfields Sites in Watersheds on the Eastern Side of Saipan: Phase 2. Impact on Aquatic Resources
Project Number:	2012GU222B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	N/A
Research Category:	Water Quality
Focus Category:	Toxic Substances, Water Quality, Conservation
Descriptors:	Surface Water
Principal Investigators:	John Starmer, Gary Denton

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

Project Title: Environmental Impact of FUDS and Brownfields Sites in Watersheds on the Eastern Side of Saipan. Phase 2: Impact on Aquatic Resources

Problems and Research Objectives

As Saipan emerged from the ravages of WWII, the disposal of wartime wastes associated with cleanup and rebuilding activities was dealt with by either dumping them at specific locations on land, or bulldozing them into the ocean. Close to two dozen such sites have been identified on Saipan under the *Formerly Used Defense Site* (FUDS) *Environmental Restoration Program* implemented by the Department of Defense in 1986 (Shimmin 2007). At least forty others have been identified under the *Brownfields Program* administered through the USEPA (Masga 2009). Inventories of materials disposed of in this way have so far been based largely on visual assessment with unexploded ordnances, munitions and demolition materials ranking among the more obvious wastes present (AMPRO 2005, ACOE 2007). What little chemical data there are indicate that heavy metals, chlorinated hydrocarbons, petroleum and polycyclic aromatic hydrocarbons are the most commonly encountered contaminants. No data exist regarding the movement of any these contaminants into other quarters of the environment via drainage pathways leading to the coast. This is especially important for the more recalcitrant, bio-accumulative compounds like heavy metals, pesticides and PCBs, which could well adversely impact on the edible quality of aquatic resources harvested for food at down-gradient locations.

In an attempt to bridge this information gap we recently examined a suit of heavy metals in soils/sediments taken in the vicinity of several dumpsites and coastal discharge points along the eastern side of Saipan, and at one dumpsite in a stream that discharged on the western side of the island (Denton and Starmer 2011). In all 32 sites were visited. While the elemental composition of the samples varied considerably between sites, the great majority were enriched with one or more heavy metals. Seven samples exceeded at least one of Saipan's environmental screening levels for heavy metals in shallow residential soils (DEQ 2005), and all exceeded at least one of USEPA's ecological soil screening levels (USEPA 2005). The follow-up investigation, described herein, uses bioindicator organisms to make a preliminary assessment of metal transport from these dumpsites into the coastal belt. The ultimate aim of this research program is to establish potential impacts of any metal enrichment on aquatic resources harvested for food.

Methodology

Dominant ecological representatives selected for this study were several species of green and brown algae, and one species of limpet (gastropod mollusks). Both groups exhibit little to no metabolic control of trace elements in their tissues and therefore tend to mirror ambient changes in metal availability in their immediate surroundings.

Specimens of each group were collected from 21 coastal sites near known or suspected inland dump sites between Agingan Point at the southern end of the island and Bird Island sanctuary in the NE corner(Fig. 1). Algal samples were collected over a reasonably wide area and pooled to provide composite samples for each species after thoroughly rinsing in ocean water. Limpets were prized from their host rocks with heavy duty, stainless steel blades and held in clean seawater for 4-6 hours to purge their gut contents.

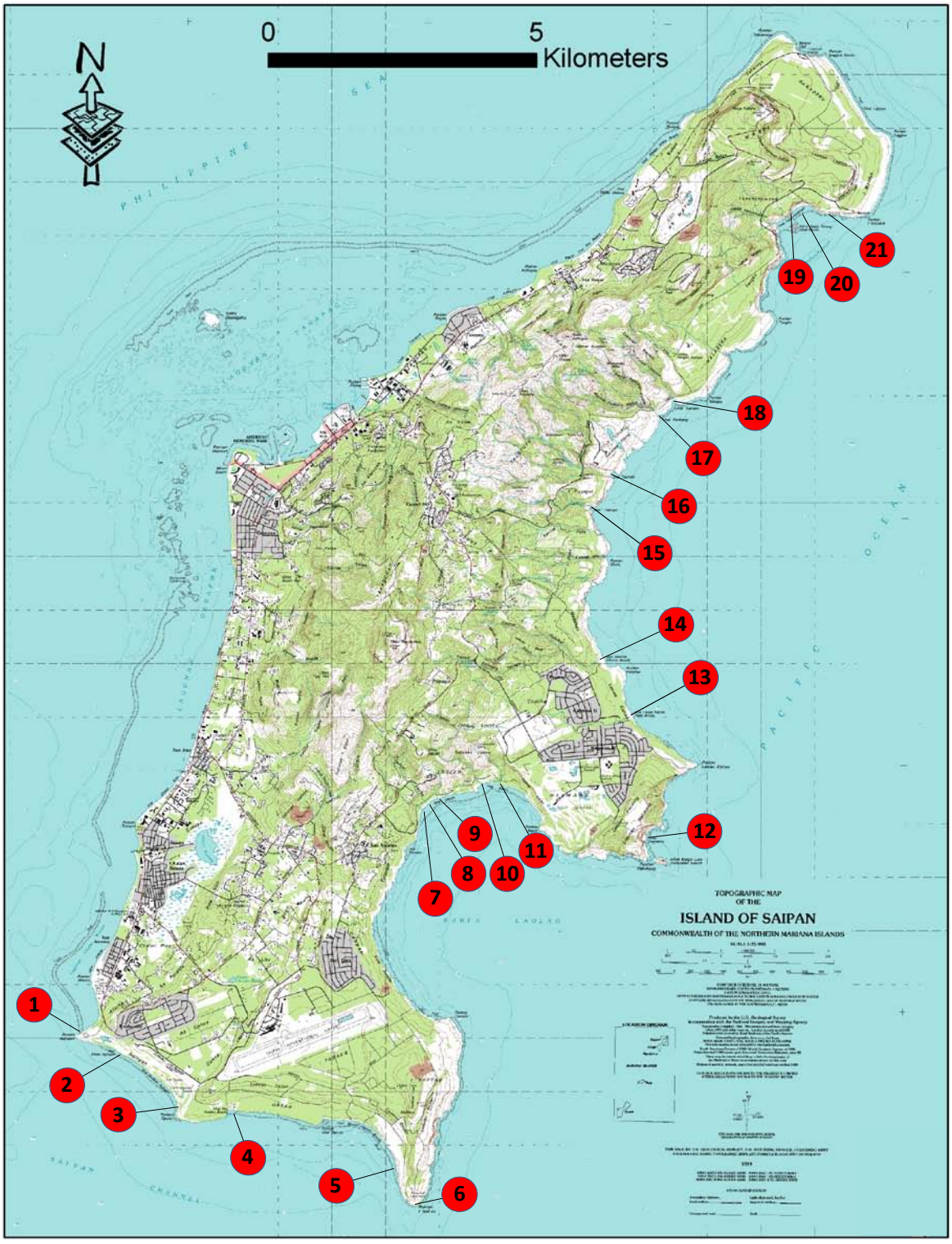

Figure 1: USGS 1-25000 topographic map of Saipan (15°12'N, 145°43'E) showing study sites at Agingan Point (sites 1), Agingan Beach (sites 2 & 3), Ladder Beach (sites 4), Obyan Beach (site 5), Obyan Point (site 6), Laulau Bay (sites 7-11), Forbidden Island (site 12), Tank Beach (site 13), Marine Beach (site 14), Old Man by the Sea Beach (site 15), Talafofo Bay (site 16), Hidden Beach (site 17), Nanasu Cove (site 18), and Bird Island (sites 19-21).

In the laboratory, samples for mercury analysis were digested in 2:1 nitric/sulfuric acids at 100^{o}C for 3 hours, made up to volume with distilled water and analyzed by flameless Atomic Absorption Spectroscopy (AAS) using the syringe technique developed by Stainton (1971). Samples for all other metal were dried to constant weight in open Ziploc bags at 60^{o}C, digested in nitric acid at 125^{o}C until oxidation was complete, and then analyzed by conventional AAS. Corrections for non atomic absorption were made simultaneously by the instrument. Recoveries for all elements from standard reference materials were in good agreement with certified values.

Principal Findings and Significance

The analytical findings to date are summarized in Tables 1 and 2 for algae and limpets respectively. Compilations of heavy metal data for similar and related species from clean and polluted environments elsewhere are presented in Table 3. Comparisons between these data and that obtained during the present study suggest that Saipan's coastal waters are, for the most part, relatively clean by world standards. Of the seaweeds analyzed, the nearshore representative, *Padina,* generally yielded higher metal concentrations than algal species collected closer to the reef crest. This is to be expected when metal inputs are primarily from land-based sources. At Agingan Point, however, sediments in the adjacent forereef are highly enriched with heavy metals as a result of past deep water dumping practices (Denton and Starmer 2011). As a consequence, metal levels were generally higher in algae taken closer to the reef crest (e.g., *Caulerpa racemosa* and *Chlorodesmis hildebrandtii*), a situation presumably caused by the backwashing of contaminated seawater from the reef slope into the lagoon. This notwithstanding, lead concentrations in all algal representatives from Agingan were indicative of substantial lead contamination in this area. Not surprisingly then, lead concentrations in limpets from Agingan Point were higher than at any other site examined. The light lead fingerprint detectable in limpets and algae between Agingan Point and Obyan Point, at the southern end of Saipan, correlates with WWII activities recorded along this stretch of coastline (AMPRO 2005). Sections of Laulau Bay were also mildly impacted by this element from sources as yet unknown.

Limpets are excellent indicators of cadmium contamination and the higher levels of this element noted in sediments along the northeast coast of Saipan last year were generally confirmed by these organisms in this year's investigation. Of particular interest were the relatively high levels encountered in limpets from the Bird Island Beach. These values are indicative of substantial cadmium enrichment when viewed against levels found in related species from polluted waters elsewhere in the world. Interestingly, the highest cadmium levels recorded in seaweed during the current study were also found at this location.

Concluding Remarks

By and large, most sights examined showed little to no metal enrichment of bioindicators for the elements examined thus far. Analysis for mercury is ongoing and will be published in the final report at the end of the year. Agingan Point is clearly a 'hot spot' area that requires additional research on metal uptake in resident biota. Local people frequently harvest seaweeds and mollusks for food from the adjacent back reef area. The submerged metallic debris and demolition material littering the forereef area also serves as a fish aggregation site and is a favored fishing spot by many. Other such submerged dumpsites exist around the island and likewise encourage fish to congregate. Considering the impact of such submerged sights on the edible quality of these fish is clearly of major importance from a public health standpoint.

Table 1: Heavy Metals in Algae from Coastal Waters on the Eastern Side of Saipan

Site (Map i.d.) and Sample	Heavy Metals (µg/g dry weight)								
	Ag	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**
AGINGAN POINT (1)									
Caulerpa racemosa	nc	nc	1.83	44.4	4027	24.1	2.95	29.2	14.8
	all <0.09	all <0.09	0.59-10.8	34.1-61.8	579-56754	5.22-233	0.89-20.4	12.3-62.7	5.69-62.4
Chlorodesmis hildebrandtii	nc	nc	2.11	48.7	3374	16.9	2.60	46.7	28.6
	all <0.19	all <0.10	1.49-2.60	25.6-76.6	2968-3676	13.8-20.4	2.12-2.99	34.2-70.7	17.8-65.7
Dictyota bartayresiana	nc	nc	2.62	14.1	2821	13.2	2.06	24.7	49.7
	all <0.19	all <0.10	2.43-2.82	13.2-14.9	2441-3437	12.7-13.7	1.82-2.26	22.9-25.9	32.1-117
Padina sp.	nc	nc	0.62	4.21	867	12.3	1.06	11.6	49.3
	all <0.10	all <0.10	0.61-0.62	3.21-5.78	838-925	8.88-17.1	0.80-1.31	9.44-13.8	45.3-54.9
Turbinaria ornata	nc	nc	nc	0.91	22.5	1.70	0.24	nc	8.03
	all <0.11	all <0.11	all <0.27	0.78-1.05	16.4-35.7	1.66-1.79	0.22-0.26	all <0.31	7.59-8.53
AGINGAN BEACH WEST (2)									
Sargassum oligosystem	nc	nc	nc	3.16	27.8	2.7	0.54	nc	12.2
	all <0.01	all <0.10	all <0.31	3.09-3.27	25.1-33.7	2.51-2.88	0.48-0.65	all <0.30	11.8-12.6
Sargassum polycystum	nc	nc	nc	3.31	69.1	9.8	1.07	1.07	16.7
	all <0.10	all <0.10	all <0.31	3.20-3.38	38.8-102	9.39-10.2	0.98-1.12	0.88-1.20	16.1-17.0
Turbinaria ornata	nc	0.11	nc	0.57	9.60	1.83	0.44	0.56	4.79
	all <0.09	<0.09-0.19	all <0.30	0.55-0.59	8.94-10.5	1.74-1.88	0.31-0.57	0.53-0.59	4.68-4.99
AGINGAN BEACH EAST (3)									
Padina sp.	nc	0.37	nc	1.00	24.6	11.2	1.74	1.36	4.58
	all <0.10	0.37-0.39	all <0.30	0.97-1.01	23.6-25.5	11.0-11.4	1.71-1.80	1.15-1.51	4.45-4.68
Sargassum polycystum	nc	0.19	nc	1.36	25.5	11.1	1.10	nc	6.97
	all <0.20	0.19-0.20	all <0.10	1.26-1.46	21.9-29.7	10.6-12.1	0.98-1.16	all <0.31	6.57-7.24
OBYAN BEACH EAST (5)									
Caulerpa racemosa	nc	nc	nc	0.9	207	6.1	1.23	nc	2.6
	all <0.10	all <0.10	<0.39-0.58	0.83-1.08	150-287	5.86-6.49	1.01-1.37	all <0.33	2.35-2.74
Chlorodesmis hildebrandtii	<0.21	<0.11	<0.45	2.68	102	13.5	2.85	<0.36	3.11
Turbinaria ornata	nc	0.39	nc	0.50	8.97	2.14	0.80	nc	2.82
	all <0.10	0.38-0.40	all <0.30	0.47-0.57	8.25-11.1	1.99-2.27	0.71-0.87	all <0.29	2.66-2.88
OBYAN POINT GULLY (6)									
Sargassum polycystum	nc	0.29	nc	1.27	31.2	11.4	4.62	nc	3.34
	all <0.10	0.29-0.30	all <0.32	1.25-1.30	19.5-55.4	10.2-12.4	4.40-4.91	all <0.31	3.08-3.49
LAULAU BAY-1 (7)									
Padina sp.	nc	0.25	0.73	0.90	368	53.1	1.07	0.84	3.97
	all <0.20	0.19-0.30	0.60-0.82	0.85-0.95	348-382	52.7-53.5	0.88-1.49	0.66-0.95	3.82-4.15
LAULAU BAY-2 (8)									
Padina sp.	nc	nc	0.59	1.44	1390	154	0.73	0.72	7.03
	all <0.20	<0.09-0.19	0.58-0.60	1.31-1.53	1235-1513	146-161	060-0.88	0.62-0.94	6.44-7.36
Sargassum polycystum	nc	0.36	1.1	1.56	859	55.8	1.83	0.35	6.39
	all <0.10	0.35-0.38	0.98-1.28	1.43-1.68	779-912	53.5-57.5	1.78-1.92	<0.27-0.60	6.21-6.62
Sargassum polycystum	nc	0.44	0.80	1.12	266	33.8	1.50	nc	4.56
	all <0.09	0.44-0.45	0.72-0.85	1.07-1.15	236-307	33.0-35.3	1.48-1.51	<0.27-0.56	4.46-4.68
Turbinaria ornata	nc	0.85	nc	0.31	36	2.08	0.46	nc	2.30
	all <0.10	0.83-0.87	all <0.31	0.28-0.37	32.8-42.0	1.56-2.42	0.31-0.64	<0.30-0.58	2.22-2.36
LAULAU BAY-3 (9)									
Padina sp.	nc	0.25	0.81	1.28	661	69.9	0.75	nc	4.85
	all <0.20	0.19-0.30	0.79-0.83	1.15-1.42	583-729	67.0-72.9	0.60-0.89	all <0.33	3.92-5.69
Sargassum oligosystem	nc	nc	1.0	1.23	502	25.8	4.36	nc	3.13
	all <0.10	all <0.10	0.88-1.18	1.08-1.37	273-946	25.5-26.4	3.72-4.82	all <0.31	2.94-3.36

Table 1: Heavy Metals in Algae from Coastal Waters on the Eastern Side of Saipan (cont.)

Site and Sample	Heavy Metals (µg/g dry weight)								
	Ag	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**
LAULAU BAY-3 (9) Cont.									
Sargassum polycystum	nc	0.19	1.19	1.57	798	41.6	1.68	nc	5.06
	all <0.10	0.18-0.20	1.04-1.29	1.47-1.69	636-942	39.6-43.9	1.56-1.86	all <0.31	4.78-5.38
Turbinaria ornata	nc	0.53	nc	0.56	35	3.01	0.34	nc	3.54
	all <0.09	0.49-0.56	all <0.30	0.49-0.63	31.0-43.8	2.88-3.16	0.28-0.46	all <0.29	3.46-3.61
LAULAU BAY-4 (10)									
Padina sp.	nc	nc	nc	0.92	489	34.0	1.44	nc	3.05
	all <0.20	all <0.20	all <0.41	0.89-0.94	465-514	33.6-34.8	1.31-1.54	all <0.33	2.80-3.19
Sargassum polycystum	nc	0.19	nc	0.71	36.3	15.6	1.26	nc	3.07
	all <0.10	0.19-0.20	all <0.32	0.66-0.79	35.1-37.6	15.1-15.9	1.15-1.34	all <0.31	2.97-3.13
Turbinaria ornata	nc	0.54	nc	0.52	36.2	2.52	0.35	nc	3.61
	all <0.10	0.48-0.58	<0.29-0.45	0.48-0.57	28.1-41.2	2.46-2.57	0.24-0.45	all <0.30	3.46-3.71
LAULAU BAY-5 (11)									
Padina sp.	nc	nc	0.50	2.44	2241	271	1.89	1.56	16.7
	all <0.01	all <0.01	0.45-0.60	2.31-2.63	2059-2421	261-282	1.62-2.13	1.44-1.76	15.5-18.4
Sargassum oligosystem	nc	nc	nc	0.99	170	8.90	0.74	nc	4.90
	all <0.10	all <0.10	all <0.30	0.79-1.13	139-231	8.33-9.48	0.62-0.86	all <0.29	4.45-5.30
Sargassum polycystum	nc	0.12	0.53	1.53	532	88.8	1.35	nc	10.5
	all <0.10	0.09-0.20	0.43-0.76	1.41-2.28	403-1534	84.0-118	1.29-.61	all <0.29	9.93-14.6
Turbinaria ornata	nc	0.40	nc	0.68	104	5.84	0.31	nc	9.85
	all <0.13	0.37-0.43	all <0.40	0.64-0.74	84.4-136	5.62-6.26	0.27-0.38	all <0.31	9.55-10.3
FORBIDDEN ISLAND (12)									
Sargassum oligosystem	nc	nc	nc	0.46	20.3	3.01	2.83	nc	0.79
	all <0.10	all <0.10	all <0.31	0.38-0.50	15.6-24.5	2.88-3.25	2.71-2.93	all <0.29	0.75-0.89
Sargassum oligosystem (young)	nc	nc	nc	0.47	18.8	6.39	3.08	nc	1.29
	all <0.18	<0.13-0.19	all <0.50	0.29-0.54	17.4-19.6	6.34-6.43	2.94-3.27	all <0.53	1.18-1.45
Sargassum oligosystem	nc	0.20	nc	0.67	83.0	21.1	4.18	nc	1.43
	all <0.10	0.19-0.22	<0.30-0.44	0.65-0.69	54.0-175	19.4-24.2	4.09-4.28	all <0.32	1.23-1.75
Sargassum oligosystem	nc	0.19	nc	0.49	20.1	12.9	3.41	nc	1.58
	all <0.10	0.18-0.19	<0.30-0.44	0.44-0.57	19.4-20.8	12.1-13.7	3.32-3.47	all <0.28	1.51-1.63
Turbinaria ornata	nc	0.20	nc	0.35	11.9	2.96	1.35	nc	0.94
	all <0.12	0.19-0.23	<0.28-0.54	0.29-0.49	10.6-12.9	2.80-3.15	1.21-1.50	all <0.34	0.87-1.02
TANK BEACH (13)									
Padina sp.	nc	nc	0.57	1.39	526	161	1.48	1.52	5.45
	all <0.01	all <0.01	0.46-0.64	0.95-1.78	496-557	152-173	0.97-2.02	1.49-1.55	3.90-7.04
Sargassum oligosystem	nc	nc	nc	0.53	25	3.8	1.54	nc	1.21
	all <0.10	all <0.10	<0.30-0.30	0.48-0.56	21.0-28.2	3.62-3.83	1.42-1.61	all <0.30	1.03-1.33
Turbinaria ornata	nc	0.18	nc	0.33	28.0	3.07	1.42	0.57	1.29
	all <0.10	0.18-0.19	all <0.30	0.27-0.37	25.2-31.1	2.97-3.28	1.24-1.57	0.55-0.58	1.19-1.39
MARINE BEACH (14)									
Padina sp.	nc	0.19	0.60	1.04	836	68.8	1.92	0.89	4.23
	all <0.10	0.19-0.19	0.46-0.75	0.86-1.17	686-1162	67.1-70.9	1.61-2.14	0.88-0.91	3.52-5.04
Cladophora sp.	nc	nc	nc	0.33	28.3	2.63	1.97	nc	1.97
	all <0.29	all <0.14	all <0.60	0.23-0.43	20.1--46.1	2.31-3.23	1.71-2.25	all <0.48	1.70-2.16
Sargassum oligosystem	nc	nc	nc	0.74	21	5.8	1.98	nc	3.93
	all <0.09	all <0.09	all <0.31	0.66-0.81	18.1-24.6	5.48-6.25	1.92-2.05	all <0.30	3.59-4.20
Sargassum polycystum	nc	0.19	nc	0.74	104	45.0	1.26	nc	2.59
	all <0.10	0.19-0.20	all <0.32	0.66-0.79	97.9-111	44.5-45.5	1.17-1.34	all <0.31	2.47-2.77
Sargassum polycystum	nc	0.18	nc	0.61	33	21.3	2.37	nc	1.30
	all <0.09	0.18-0.19	all <0.30	0.54-0.66	20.9-43.3	19.8-22.5	2.28-2.42	all <0.29	1.17-1.43

Table 1: Heavy Metals in Algae from Coastal Waters on the Eastern Side of Saipan (cont.)

Site and Sample	Heavy Metals (µg/g dry weight)								
	Ag	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**
OLD MAN BY THE SEA BEACH (15)									
Padina sp.	nc	nc	3.1	2.16	5273	94.3	1.64	0.77	1.99
	all <0.10	all <0.10	2.46-3.88	2.06-2.22	3031-11885	83.8-110	1.57-1.78	0.59-0.89	1.81-2.22
Sargassum polycystum	nc	0.25	0.48	1.21	311	23.4	1.61	nc	3.89
	all <0.09	0.21-0.28	0.39-0.58	1.10-1.41	221-481	22.0-26.8	1.59-1.65	all <0.28	3.57-4.60
Turbinaria ornata	nc	0.52	0.57	0.78	134	4.86	0.60	nc	3.00
	all <0.19	0.47-0.58	0.44-0.90	0.76-0.81	78.5-205	4.09-5.67	0.49-0.76	all <0.30	2.75-3.34
TALAFOFO BAY (16)									
Padina sp.	nc	nc	2.87	0.92	6664	190	2.11	0.78	12.3
	all <0.10	all <0.10	2.50-3.33	0.87-1.01	5246-9123	180-202	2.00-2.19	0.58-0.92	10.7-14.9
Sargassum oligosystem	nc	0.19	nc	0.68	12.0	2.25	1.16	nc	3.57
	all <0.10	0.19-0.20	all <0.31	0.57-0.78	11.8-12.4	2.17-2.30	1.06-1.23	all <0.29	3.44-3.69
Sargassum polycystum	nc	0.19	nc	0.81	38.4	19.8	1.58	nc	3.78
	all <0.01	0.19-0.20	all <0.30	0.69-1.05	32.6-44.2	19.3-20.2	1.54-1.60	all <0.29	3.55-4.16
HIDDEN BEACH (17)									
Padina sp.	nc	0.28	2.06	2.28	2881	263	2.23	0.59	2.03
	all <0.10	0.28-0.29	1.84-2.37	2.19-2.39	2641-3370	257-273	2.10-2.34	0.57-0.59	1.90-2.12
Sargassum polycystum	nc	0.38	nc	1.04	181	10.9	2.30	nc	3.99
	all <0.09	0.35-0.41	<0.23-0.56	0.83-1.27	104-464	9.01-14.7	2.17-2.49	all <0.26	3.78-4.71
NANASU COVE (18)									
Padina sp.	nc	nc	nc	0.63	170	17.0	1.39	0.89	2.62
	all <0.10	all <0.10	all <0.31	0.56-0.68	117-225	14.1-19.4	1.12-1.60	0.88-0.91	2.37-3.12
Turbinaria ornata	nc	0.26	nc	0.52	14.53	2.40	0.47	nc	1.91
	all <0.10	0.24-0.29	all <0.30	0.48-0.59	10.8-18.7	2.29-2.47	0.36-0.55	all <0.28	1.82-2.04
Sargassum oligosystem	nc	0.20	nc	1.11	42.4	3.65	1.75	nc	1.94
	all <0.10	0.19-0.20	all <0.31	1.07-1.20	28.9-90.5	3.25-4.76	1.70-1.87	all <0.29	1.87-2.08
Sargassum oligosystem	nc	0.28	nc	0.78	80.7	10.13	3.96	nc	2.30
	all <0.15	0.28-0.30	all <0.30	0.75-0.89	65.4-102	9.58-11.4	3.64-4.25	all <0.30	2.07-2.66
BIRD ISLAND BEACH (20)									
Padina sp.	nc	1.08	0.71	2.39	1369	220	2.33	0.78	9.67
	all <0.10	1.04-1.17	0.61-0.92	2.29-2.46	1124-1594	214-225	2.25-2.42	0.59-0.91	9.34-9.86
Sargassum oligosystem	nc	0.22	nc	1.47	127	7.43	0.97	nc	3.92
	all <0.10	0.19-0.29	<0.28-0.45	1.35-1.57	111-175	7.00-8.60	0.86-1.06	all <0.29	3.59-4.49
Turbinaria ornata	nc	0.14	0.34	0.34	12.5	1.35	2.37	nc	0.92
	all <0.11	<0.11-0.21	<0.35-0.49	0.32-0.36	10.4-16.0	1.25-1.43	2.23-2.54	all <0.33	0.80-1.01
ALL SITES (1-20)									
max mean	<0.10	1.08	3.06	48.7	6664	271	4.62	46.7	49.7
min mean	<0.10	<0.10	<0.30	0.31	8.97	1.35	0.24	<0.30	0.79
median mean	<0.10	0.12	<0.30	0.93	76	11.8	1.43	<0.30	3.95

Values shown for each site are geometric means and ranges of 3-5 replicate samples.

Table 2: Heavy Metals in Limpets from Coastal Waters on the Eastern Side of Saipan

Site (Map i.d.)	Shell dimensions (cm)		Heavy Metals (µg/g dry weight)								
	L	W	Ag	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
AGINGAN POINT (1)	2.41	2.01	nc	3.41	4.64	3.99	558	2.55	3.09	2.36	102
	2.12-2.69	1.76-2.26	all <0.10	2.99-3.96	4.24-4.99	8.73-4.36	431-719	2.31-2.82	2.85-3.44	2.11-2.85	83.2-133
AGINGAN BEACH -WEST (2)	2.26	1.83	nc	3.92	4.13	4.88	471	3.31	2.10	0.66	195
	2.03-2.50	1.63-2.06	all <0.10	2.94-5.31	4.04-5.39	4.31-4.95	4.07-5.39	3.13-3.74	1.72-2.34	0.58-0.87	179-234
AGINGAN BEACH-EAST (3)	2.31	1.89	nc	4.29	6.06	3.65	447	2.67	3.14	0.58	78.2
	2.10-2.61	1.73-2.13	all <0.13	3.58-4.82	5.22-6.95	3.34-3.78	394-523	2.04-3.22	3.09-3.26	0.48-0.80	65.1-98.9
LADDER BEACH (4)	2.12	1.76	nc	3.63	0.77	3.89	484	3.24	4.05	0.71	130
	1.90-2.30	1.50-2.00	all <0.09	3.18-4.16	0.75-0.97	3.29-4.45	437-533	2.58-4.14	3.58-4.47	0.58-0.78	109-166
OBYAN BEACH-EAST (5)	2.69	2.21	nc	4.43	1.45	5.11	249	3.77	5.14	0.60	134
	2.40-2.92	1.94-2.43	all <0.10	3.63-5.02	1.24-2.04	4.68-5.65	200-344	2.79-5.09	4.37-6.25	0.48-1.00	96.6-178
OBYAN POINT GULLY-EAST FACE (6)	2.04	1.67	nc	2.45	1.98	2.91	237	3.00	2.22	nc	24.8
	1.83-2.25	1.49-1.83	all <0.11	2,40-2.49	1.80-2.15	2.82-2.96	224-247	2.74-3.52	1.98-2.51	all <0.28	19.9-31.2
OBYAN POINT GULLY-WEST FACE (6)	2.20	1.79	nc	4.10	3.23	3.16	266	1.61	4.30	nc	25.6
	1.93-2.54	1.57-2.06	all <0.13	3.01-5.16	2.80-3.80	2.69-3.63	171-392	1.24-1.81	3.55-5.03	all <0.43	17.1-34.0
LAULAU BAY-1 (7)	2.01	1.61	nc	9.22	6.67	3.47	973	2.84	3.93	1.44	120.4
	1.75-2.33	1.36-1.92	all <0.11	6.95-11.0	4.48-9.21	3.07-3.75	819-1125	2.61-3.15	3.20-4.36	1.24-1.85	111-144
LAULAU BAY-3 (9)	2.16	1.74	nc	3.47	0.49	3.50	339	3.68	3.98	nc	45.8
	1.91-2.37	1.49-1.92	all <0.11	2.89-4.32	0.47-0.52	3.37-3.77	303-376	3.09-4.66	3.64-4.32	all <0.37	38.8-53.0
LAULAU BAY-4 (10)	2.33	1.86	nc	1.67	0.38	2.68	321	3.10	5.50	nc	37.3
	1.86-2.66	1.48-2.14	all <0.13	1.27-1.93	0.28-0.52	2.26-3.00	276-376	2.59-3.85	4.99-6.47	all <0.40	34.3-43.5
LAULAU BAY-5 (11)	2.07	1.65	nc	3.38	0.61	3.33	565	2.93	2.01	nc	106
	1.74-2.46	1.36-1.99	all <0.11	2.27-5.28	0.57-0.66	2.89-3.64	489-621	2.49-2.77	1.92-2.07	all <0.22	70.7-193
FORBIDDEN ISLAND (12)	2.20	1.84	nc	8.32	4.26	2.53	1005	2.28	1.19	nc	84.4
	1.98-2.41	1.65-2.03	all <0.13	6.72-8.09	3.41-5.23	2.31-2.83	774-1128	2.09-2.56	0.94-1.41	all <0.40	79.6-95.1
TANK BEACH (13)	2.15	1.76	nc	2.24	4.05	3.35	401	4.10	4.04	nc	48.3
	2.01-2.31	1.62-1.89	all <0.10	1.92-2.80	2.94-8.29	3.27-3.54	365-439	3.66-4.57	3.87-4.37	<0.31-0.70	41.3-53.2
MARINE BEACH (14)	2.00	1.65	nc	10.7	1.95	4.40	753	5.07	4.24	0.50	98.0
	1.82-2.21	1.50-1.83	all <0.12	9.13-12.2	1.57-2.36	4.22-4.70	730-784	4.79-5.30	3.96-4.60	<0.38-0.82	84.4-110
OLD MAN BY THE SEA BEACH (15)	1.97	1.63	nc	8.51	5.35	3.31	1001	3.40	3.93	nc	50.5
	1.73-2.32	1.42-1.97	all <0.10	7.95-8.93	4.24-7.09	2.94-3.71	886-1128	2.92-4.34	3.39-5.01	all <0.27	23.2-77.9
TALAFOFO BAY-SOUTH SIDE (16)	1.80	1.44	nc	6.85	1.09	2.47	670	3.45	1.28	nc	40.0
	1.50-2.20	1.24-1.70	all <0.15	4.96-8.21	0.56-1.62	2.05-2.81	349-1025	3.02-4.13	0.99-1.53	all <0.50	38.0-42.1
TALAFOFO BAY-NORTH SIDE (16)	2.07	1.70	nc	13.8	5.13	3.76	966	4.27	4.77	nc	99.5
	1.89-2.25	1.56-1.85	all <0.12	11.8-17.8	4.84-5.70	3.54-4.08	850-1007	3.67-5.20	4.64-4.99	all <0.41	80.4-127
HIDDEN BEACH (17)	1.83	1.50	nc	10.4	1.68	2.55	807	9.28	4.39	nc	75.8
	1.64-2.00	1.32-1.67	all <0.10	8.25-12.6	1.52-1.83	2.33-2.73	739-870	5.99-13.8	4.27-1.45	all <0.25	73.9-79.4
NANASU COVE (18)	2.08	1.71	nc	6.68	5.02	3.51	810	3.26	4.35	nc	50.9
	1.81-2.34	1.48-1.93	all <0.13	5.09-9.07	3.87-6.13	3.43-3.63	684-9.41	3.12-3.36	3.61-4.82	all <0.43	39.4-66.5
BIRD ISLAND (19)	2.52	2.05	nc	42.4	3.75	3.72	439	5.10	5.27	nc	198
	2.16-2.77	1.77-2.30	all <0.09	32.8-58.8	2.89-5.48	3.42-3.99	358-547	3.34-10.9	4.84-5.82	all <0.30	180-222
BIRD ISLAND (21)	2.43	2.00	nc	27.1	2.74	3.59	526	3.78	4.01	nc	115
	2.01-2.79	1.65-2.34	all <0.11	19.5-37.6	2.40-3.05	3.32-3.99	492-545	2.72-5.57	2.51-5.59	all <0.35	90.4-141
ALL SITES (1-21)											
max mean	2.69	2.21	<0.10	42.4	6.67	5.11	1005	9.28	5.50	2.36	198
min mean	1.80	1.44	<0.10	1.67	0.38	2.47	237	1.61	1.19	<0.20	24.8
median mean	2.15	1.76	<0.10	4.43	3.23	3.50	526	3.31	4.01	<0.30	84.4

Values shown for each site are geometric means and ranges of 3-5 pooled samples of 6-8 limpets.

Table 4: Heavy Metals in Similar and Related Species of Algae and Limpets from Clean and Polluted Waters Elsewhere

Species	Location	Pollution Status	Heavy Metals (µg/g dry weight)									Reference
			Ag	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	
Algae (stipe and frond):												
Caulerpa racemosa	Gt. Barrier Reef, Australia	Clean to Light	-	0.1-0.5	-	1.4-2.6	-	-	0.8-2.6	<0.7-2.4	0.3-10	Denton & Burdon-Jones, 1986
Chlorodesmis fastigiata	Gt. Barrier Reef, Australia	Clean to Light	-	0.1-0.6	-	1.4-2.4	-	-	0.4-1.7	0.62.1	1.3-12	Denton & Burdon-Jones, 1986
Padina tetrostromatica	Townsville Harbor	High	<0.1	<0.4	31.5	58.9	6429	818	13.1	108	440	Burdon-Jones *et al.*, 1975
Padina sp.	Apra Harbor, Guam	Moderate to High	all <0.1	0.2-0.5	1.3-3.0	2.6-37	-	-	1.1-3.2	2.6-6.5	45.1-192	Denton *et al.*, 2006
Padina australis	Gt. Barrier Reef, Australia	Clean to Light	-	0.4-0.6	-	2.0-3.0	-	-	1.0-1.4	<0.9-5.0	3.8-9.5	Denton & Burdon-Jones, 1986
Padina boyana	Pago Bay, Guam	Clean to Light	all <0.2	<0.2-0.3	<0.2-2.1	0.7-4.7	262-1516	19.0-108	1.6-3.4	0.3-14	2.8-8.3	Denton *et al.*, 2008
Padina sp.	Tanapag Lagoon, Saipan	Light to Moderate	<0.10-0.3	<0.1-1.7	<0.3-1.4	1.3-25	-	-	0.9-1.7	<0.3-15	5.3-107	Denton *et al.*, 2009
Sargassum polycystum	Tanapag Lagoon, Saipan	Light to Moderate	all <0.2	0.3-0.4	<0.3-0.6	1.3-1.5	-	-	0.8-1.2	0.4-0.5	13-16	Denton *et al.*, 2009
Sargassum cristafolium	Pago Bay, Guam	Clean to Light	all <0.2	<0.2-0.3	<0.2-1.2	0.5-1.6	17.3-653	2.6-41	0.7-5.1	<0.2-3.0	0.8-4.83	Denton *et al.*, 2008
Sargassum polycystum	Pago Bay, Guam	Clean to Light	all <0.2	<0.2-0.3	0.60-2.7	0.9-2.8	236-1765	53-101	1.5-5.1	<0.3-1.5	2.6-7.0	Denton *et al.*, 2008
Sargassum sp.	Townsville, Australia	Clean to Light	all <0.2	all <0.2	<0.4-3.1	2.2-3.1	1186-1398	30-49	<0.3-1.1	all <0.4	7.0-10	Burdon-Jones *et al.*, 1975
Turbinaria orata	Gt. Barrier Reef, Australia	Clean to Light	-	0.2-0.4	-	0.8-1.5	-	-	<0.9-1.3	all <0.6	0.9-3.6	Denton & Burdon-Jones, 1986
Limpets (whole flesh):												
Patella vulgata	Bristol Channel, UK	Very High	-	467-780	-	27-43	-	-	-	1.0-3.0	453-1733	Peden *et al*. 1973
Patella vulgata	Severn Estuary, UK	Very High	-	550	-	14	-	-	-	9.5	580	Butterworth *et al*. 1972
Patella vulgata	Solent Estuary, UK	High	-	2.7-8.1	-	-	-	-	-	-	95-229	Leatherland and Burton, 1974
Patella vulgata	Looe Estuary, UK	High	1.5-6.0	3.3-22	0.5-2.6	10-27	891-2330	5.4-36	1.7-3.7	5.1-38	83-224	Bryan and Hummerstone 1977
Patella vulgata	Trondheimsfjorden, Norway	High	<0.1-4.0	7.0-22	7.0-17	12-30	1289-2505	-	4.0-11	-	127-238	Lande 1977
Patella vulgata	Irish Sea	Clean to Light	-	31	-	7.7	150	13	2.5	32	84	Segar *et al.* 1971
Patella vulgata	Irish Sea	Clean to Light	-	16.4	-	-	-	-	-	-	-	Mullin and Riley, 1956
Patella vulgata	UK Coastal Waters	Clean to Light	2.1	13.1	-	14	2450	42	7.3	7.9	158	Preston *et al.* 1972
Patella sp.	Townsville, Australia	Clean to Light	all <0.2	2.7-5.0	<0.2-6.9	3.6-7.8	822-1748	3.7-15	2.8-5.3	<0.5-3.1	52-89	Denton (unpublished data)

Literature Cited

ACOE (2007). Revised Final Statewide Management Action Plan (SMAP) for Defense Environmental Restoration Program Formerly Used Defense Sites (DERP-FUDS) within the Commonwealth of the Northern Mariana Islands. *Prepared by the ACOE Pacific Ocean Division, Honolulu Engineer District,* June 27, 2007.

AMPRO (2005). Unexploded Ordnance, Historical Research and UXO Assessment. Saipan Commonwealth of the Northern Mariana Islands. *Report prepared by AMPRO Ordnance and Explosives Experts,* December 10, 2005.

Bryan, G.W. and L.G. Hummerstone (1977). Indicators of Heavy Metal Contamination in the Looe Estuary (Cornwall) with particular Regard to Silver and Lead. Journal of the Marine Biological Association of the UK., 57: 75-92.

Burdon-Jones, C., G.R.W. Denton, G.B. Jones and K.A. McPhie (1975). Long-Term Sub-Lethal Effects of Metals on Marine Organism. Part I Baseline Survey. Final Report to the Water Quality Council of Queensland, Australia. 105 pp.

Butterworth, J., P. Lester and G. Nickless (1972). Distribution of Heavy Metals in the Severn Estuary. Marine Pollution Bulletin, 3: 72-74.

Denton, G.R.W. and Starmer J.A. (2011). Environmental Impact of FUDS and Brownfields Sites in Watersheds on the Eastern Side of Saipan. Phase 1: Chemical Integrity of Soils and Sediments *104-B Project Synopsis Report.* **In**: WERI FY-2011 Annual Report to USGS, pp 41-48.

Denton, G.R.W., Morrison, R.J., Bearden, B.G., Houk, P., Starmer, J.A. and Wood, H.R. (2009). Impact of a Coastal Dump in a Tropical Lagoon on Trace Metal Levels in Surrounding Marine Biota: A Case Study from Saipan, Northern Mariana Islands (CNMI). *Marine Pollution Bulletin,* 58: 424-455.

Denton, G.R.W. and R.J. Morrison (2008). Impact of a Rudimentary Landfill on the Trace Metal Status of Pago Bay, Guam. *Marine Pollution Bulletin,* 58: 150-162.

Denton, G.R.W., Concepcion, L.P., Wood, H.R. and Morrison R.J. (2006). Trace Metals in Marine Organisms from Four Harbours in Guam. *Marine Pollution Bulletin,* 52: 1786-1804.

Denton, G.R.W. and C, Burdon-Jones (1986). Trace Metals in Algae from the Great Barrier Reef. Marine Pollution Bulletin, 17: 98-107.

DEQ (2005). Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater. Volume 1. Summary Tier 1 Lookup Tables. *Saipan Division of Environmental Quality, Commonwealth of the Northern Mariana Islands (CNMI) Report Prepared by Hawai'i Department of Health, Hazard Evaluation and Emergency Response.*

Lande, E. (1977). Heavy Metal Pollution in Trondheimsfjorden, Norway, and the Recored Effects on the Flora and Fauna. Environmental Pollution, 12: 187-198.

Leatherland, T.M. and J.D Burton (1974). The Occurrence of Some Trace Metals in Coastal Organisms with Particular Reference to the Solent Region. Journal of the Marine Biological Association of the UK., 54: 457-468.

Masga, R. (2009). DEQ Discusses Brownfields Super fund Law. *Mariana Variety Newspaper* Friday August 7, 2009. Story Reported by Andrew O. De Guzman - Variety News Staff.

Mullin, J.B. and J.P. Riley (1956). The Occurrence of Cadmium in Seawater and in Marine Organisms and Sediments, Joural of Marine Research, 15: 103-122.

Peden, J.D., J.H. Crothers, C.E. Waterfall and J. Beasley (1973). Heavy Metals in Somerset Marine Organisms. Marine Pollution Bulletin, 4: 7-9.

Preston, A., D.J. Jefferies, J.W.R. Dutton, B.R. Harvey and A.K. Steele (1972). British Isles Coastal Waters: The Concentrations of Selected Heavy Metals in Seawater, Suspended Sediments and Biological Indicators - A Pilot Survey. Environmental Pollution, 3: 69-82.

Segar, D.A., J.D. Collins and J.P. Riley (1971). The Distribution of Major and Minor Elements in Marine Animals. Molluscs. Journal of the Marine Biological Association of the UK., 51: 131-136.

Shimmin, K. (2007). FUDS and OE Contamination in Guam, CNMI, and Off-Shore Pacific Waters: Potential Impact on an Oil-Hazmat Response & How To Get Assistance. Oceania Regional Response Team Meeting, April 24, 2007. For further information contact Kathleen Shimmin, FUDS Program Manager, USEPA-IX. Email: shimmin.kathleen@epa.gov.

Stainton, M.P. (1971). Syringe Procedure for the Transfer of Nanogram Quantities of Mercury Vapor for Flameless Atomic Absorption Spectrophotometry. *Analytical Chemistry*, 43: 625-627.

USEPA (2005). Guidance for Developing Ecological Soil Screening Levels (OSEWR Directive 9285.7-55). *U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response,* 1200 Pennsylvania Avenue, N.W. Washington, DC 20460.

Inventory and Assessment of Existing Sewage Treatment Facilities and Excess Sludge Handling Practices in the Federated States of Micronesia

Basic Information

Title:	Inventory and Assessment of Existing Sewage Treatment Facilities and Excess Sludge Handling Practices in the Federated States of Micronesia
Project Number:	2012GU223B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	N/A
Research Category:	Engineering
Focus Category:	Waste Water, Treatment, Methods
Descriptors:	Wastewater, Sewage, Treatment, Excess Sludge, Disposal, Discharge, Septic Tank, Micronesia
Principal Investigators:	Joe Rouse

Publications

1. Joseph D. Rouse, 2013, Assessment of Wastewater Treatment Facilities and Excess Sludge Handling Practices in the Federated States of Micronesia: Sustainability of Wastewater Treatment Practices, Ninth International Conference on Environmental, Cultural, Economic & Social Sustainability. Hiroshima, Japan; January 23-25, 2013 (Virtual Participant). (www.onsustainability.com ; link to: ; or, www.youtube.com/playlist?list=PL428534F575A9451A&feature=view_all)
2. Joseph D. Rouse, 2013, Assessment of Wastewater Treatment Facilities and Excess Sludge Handling Practices in the FSM, 35th Annual Conference of the Hawaii Water Environment Association. Honolulu, Hawaii; February 4-6, 2013. Presentation 36.

PROJECT SYNOPSIS REPORT

Project Title: Inventory and assessment of existing sewage treatment facilities and excess sludge handling practices in the Federated States of Micronesia

Problem and Research Objectives

The existing wastewater/sewage treatment facilities in the Federated States of Micronesia are not adequately inventoried. Furthermore, the limited information that is available is largely esoteric in nature, being available only to a few persons engaged at the local level. Items of interest include the types of unit processes being used (activated sludge, bio-filter, ponds), degree of treatment being targeted (primary, secondary, tertiary), design capacities (flow rate, loading rate), degrees of treatment being achieved (removal efficiency, regulatory compliance), and locations where treated effluents are being discharged. Of equal concern is the handling of excess sludge generated at wastewater treatment plants, including the methods being used for treatment and disposal of waste sludge (or reuse of biosolids). In addition, the current conditions of wastewater collection lines and their extent of service coverage (number of household connections) and the presence of industrial wastewater inputs are important factors.

The lack of fully functional wastewater treatment systems or the use of methods that are not fully sustainable at the local level may lead to adverse environmental impacts and public health concerns. Thus, it was proposed to carry out a comprehensive study of the major population centers in Yap, Chuuk, Pohnpei, and Kosrae states to document the current conditions of their wastewater collection and treatment systems and sludge handling practices. Such information needs to be made available to enhance our knowledge of where potential problems exist and to assist in planning for future improvements with a goal of developing sustainable wastewater treatment infrastructures throughout the Federated States of Micronesia.

Accordingly, the objective of the proposed project was to compile a technical report with up-to-date information on the existing wastewater collection and treatment systems and sludge handling in the region of concern. The findings of this project will assist in identifying and prioritizing areas where further work is needed to improve wastewater treatment practices. Furthermore, it would be useful as a planning tool by allowing for comparisons of results obtained at different locations throughout the expansive reaches of Micronesia. As a conclusion to the study, an overview will be compiled to tie together the above observations and itemize possible courses of corrective action with a goal of developing sustainable wastewater treatment infrastructures throughout the region.

Methodology

To meet the objective of this study a detailed inventory was compiled consisting of up-to-date information about the existing wastewater treatment facilities in the population centers of Yap, Chuuk, Pohnpei, and Kosrae of the Federated States of Micronesia. The inventory items targeted the following info:

(i) Description of types of systems being used, including unit processes and flow diagrams
(ii) Determination of volumes of main units and design capacities (if known)
(iii) Determination of present conditions as to the flows being treated and efficiencies being achieved
(iv) Identification of treatment requirements (including regulatory standards)
(v) Determination of discharge practices for the treated effluents
(vi) Description of excess sludge handling and disposal practices (including quantification as practicable)
(vii) Description of collection methods (e.g., pipes, trucks) used to get wastewater to the treatment site (including extent of coverage as practicable)
(viii) Identification of any known plans for future works

While the focus of the study was on centralized wastewater treatment plants, delineation of districts where individual dwellings are relying on septic tanks/pits or packaged treatment units was also conducted, without getting into detailed inspections of each unit. Likewise, where related issues of either domestic or industrial origins were discovered, a best attempt was be made to describe the situation.

The methods that were employed over the course of this project included civil and environmental engineering fieldwork. All work was carried out under the supervision of the principal investigator. Prior to commencing fieldwork, points of contact were established in each state to clarify the purpose of the investigation prior to proceeding with preliminary inquiries and gathering of relevant information by means of personal direct communication.

Fieldwork started by meeting with pertinent local officials on utility boards and other government agencies to review previously received preliminary information and gather additional information concerning locations and specific details of regional wastewater treatment facilities. Subsequently, visits were conducted to all known treatment facilities to document the attributes itemized above. In addition, all other relevant features were documented and photographs taken for inclusion in the final report.

A concerted effort was made to glean a complete overview of the regional wastewater and disposal practices including plans for future work from informal conversations with operators and formal interviews with local state officials. Prior to leaving any particular area, every effort was made to synthesize the findings and see if any outstanding questions remained to be answered.

Having completed the fieldwork portion of the project, the the final technical report including photo documentation will be prepared. This comprehensive report will be created as a WERI technical report and will be distributed to stakeholders as needed.

Principal Findings and Significance

A comprehensive survey of the major population centers in the four states reveled that the situation in Pohnpei, location of the capital and commercial center of the FSM, is largely under control. In the other states, though, a lack of functional wastewater treatment systems and conditions that could potentially lead to adverse environmental impacts and public health concerns were evident. In some cases raw sewage is being continuously discharged directly into the ocean by relatively short outfalls. In addition, local operators, though very dedicated to their work, do not know the amount or composition of the wastewater entering their plants nor the quality of the effluent. Economic constraints often seem to be the hindrance to successful O&M and capital improvement programs.

A repeatedly encountered question during interviews with local authorities addressed a need to know the treatment requirements for sewage sludge so that it can be safely and beneficially used as a biosolids product. At locations where settled sludge is periodically collected, it is immediately whisked away by local farmers for agricultural use despite the lack of adequate treatment, thus stressing the need for regulatory supervision and technological advancement in this area. In addition, the need to establish best management practices for placement and maintenance of septic tanks is being sought after with a sense of urgency.

Only a few highlights of the survey will be summarized here, state by state: Firstly, on the island of Kosrae water and wastewater are managed under the Department of Transportation and Infrastructure; it is hoped, though, that a new Kosrae Utilities Authority (KUA) will be formed soon to assume this responsibility. There is one wastewater treatment system on the island consisting of three oxidation ponds functioning in series (Figure 1). Input to the system is from a sewer line servicing the hospital, community college and high school. The average inflow is estimated to be only about 1000 gal/day and treated outflow discharges to the Tofol River. The system appears to be working well, though no sample analyses are being conducted. 15 to 20 years ago, by government directive 1165 septic tanks were installed, which constitutes about 94% coverage for the island. While the septic-tank culture seems to be working well, in the village of Lelu where there is not enough space for individual leaching fields, a collection network was installed which discharges the partially treated effluent from 350 tanks directly to the ocean bay. In addition, a new landfill was installed in 2010 including a well functioning leachate collection system. Leachate is collected in a catch pond before passing through a gravel-sand filter and on to the coastal mangrove. The leachate is tested for chemical oxidation demand and has never surpassed the 100 mg/l regulatory limit.

Figure 1. Areal photo of the sewage treatment system in Kosrae consisting of three oxidation ponds.

In Pohnpei, there is a contact-stabilization type activated-sludge wastewater treatment plant in Kolonia on the main island that is said to be about 60 years old (Figure 2). The plant was designed for 700 house-hold connections, but is thought to be serving 2 to 3 times that amount now. Accordingly, a new plant of the same type and capacity is under construction parallel to the old plant to double the capacity. However, it is said that data analyses have not been conducted for about 10 years, thus the actual flow rate and treatment efficiency are not known. While the existing plant does appear to be functioning properly, the activated sludge appears to be much too thin, thus effluent quality would be a point of concern; furthermore, the outfall discharges only about 1000 ft from the shore into the crowded bay.

Figure 2. Photo of existing contact-stabilization activated-sludge sewage treatment plant in Pohnpei.

There is also a contact-stabilization type activated-sludge wastewater treatment plant on Weno Island of Chuuk state that is about 40 years old (see Figure 3). However, it is not

currently in use and has been out of operation for several years. Untreated sewage is thus bypassing the plant and being discharged in the lagoon. The amount being discharged, though, may not be very great because much of the collection network has been out of operation due to grinder-pump stations and lift stations being under repair. The Chuuk Public Utilities Corporation (CPUC) is very busy and making good progress towards getting the network back on line in preparation for the anticipated refurbishing of the old treatment plant.

Figure 3. Photo of inoperative sewage treatment plant on Weno Island in Chuuk.

On the island of Yap (Figure 4), the sewage treatment plant consists of an Imhoff tank system (duel units in parallel). While Imhoff tanks have the advantage of less operational requirements, they are not known to provide much treatment power, other than removal of settled solids. In addition, the outfall from the plant is known to be broken and discharging sewage at about 500 ft from the shore. The local utilities and regulatory officials are busy working on evaluating and upgrading various issues including installation of new septic tanks. Furthermore, a new landfill is to be designed and constructed that will include proper leachate collection, possibly requiring treatment.

Figure 4. Photo of Imhoff tank sewage treatment system in Yap.

Wastewater treatment requirements vary for different communities throughout the FSM; however, some similarities in the treatment needs on these tropical islands do exist. Accordingly, comparisons of methods being used and the results obtained at different locations will be of value for planning purposes. Such information is needed to assist in decision making for future improvements with a goal of developing sustainable wastewater treatment infrastructures throughout Micronesia and other tropical island communities.

Improving the Weno, Chuuk Water Distribution System Using Hydraulic Modeling and Geographic Information Systems

Basic Information

Title:	Improving the Weno, Chuuk Water Distribution System Using Hydraulic Modeling and Geographic Information Systems
Project Number:	2012GU227B
Start Date:	3/1/2012
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Principal Investigators:	Shahram Khosrowpanah, Leroy F. Heitz

Publication

1. Heitz, F. Leroy, Shahram Khosrowpanah, 2013, Improving the Weno, Chuuk Water Distribution System Using Hydraulic Modeling and Geographic Information Systems, Water and Environmental Research Institute (WERI), University of Guam, Mangilao, Guam, Report No. 140, 50 pp.

PROJECT SYNOPSIS REPORT

Project Title: Improving the Weno, Chuuk Water Distribution System Using Hydraulic Modeling and Geographic Information Systems

Problem and Research Objectives

Water hours and low delivery pressure have long been a part of the daily lives of the people in the Micronesian Islands. The problems with delivery of adequate supplies of water to the customers at appropriate pressure have become more and more of a challenge to public utilities throughout these islands. This is particularly true on the island of Weno in Chuuk State, Federated States of Micronesia (FSM).

Over the years the Chuuk Public Utility Commission's (CPUC) water distribution system has grown without adequate documentation as to the extent and size of supply and transmission resources and where these resources are located. Just at the turn of the century several new wells were added to the CPUC's water supply system. In 2003 and 2004 investigators from the University of Guam Water and Environmental Research Institute (WERI) gathered water quality information from all the existing wells and developed a preliminary map of the water delivery system. Since then many changes and additions have made to the delivery system.

This objective of this project was to develop a set of management and engineering tools, which the planning, operation, and engineering staffs at CPUC can use to better plan, operate, and maintain the water delivery system. These tools will assist CPUC develop a water system that can deliver adequate water to all the households in Weno on a continuous basis with sufficient pressure.

The first management tool that was developed was a computerized water system network model. This model was developed using information gathered from previous studies and additional information documenting changes and additions to the system since the original data was gathered. Other information such as system pressure and flows was gathered as part of the calibration process of this model. The model will be available to the CPUC engineering and planning staffs to help in pinpointing problems areas and to explore operations options for improving system performance. The model was developed using the free water distribution modeling program "EPANET".

The second tool developed was a Geographic Information System based (GIS) inventory of system resources. This GIS system describes the water sources available, the well systems in place, water storage facilities and major transmission lines in the distribution system. The GIS system consists of maps showing the location of the various components of the water transmission system and ancillary equipment. The GIS will be available to managers and engineers so that they can explore various scenarios for long range planning for system maintenance and improvements. The GIS will also be available to operations personnel so that they can maximize their resources for responding to emergencies, planning repairs, and purchasing the inventory of spare parts needed by the utility.

Methodology

This project was divided into three phases. These three phases are described in the following sections.

Phase I. Gather a complete physical and hydraulic description of the Weno water distribution system

Information gathered during the 1986 study (Heitz, 1986) was used as the starting point for this phase. Since the EPANET model used in this study is a graphics based model it was necessary to secure a high quality base map to use as the basis for mapping the locations of the pipes, pumps, and tanks that were part of the system. A Lakewood, Colorado, USA company named Digital Data Services was retained to digitize a clean fresh US Geological Survey Quadrangle Topographic Map of Weno Island. After procuring the map they made a high resolution digital scan of the map. This digitized map served as the base map for all of the future work that was done on the project. Along with digitizing the base map, they also created separations of the contour lines that were included on the map. These separations were later used to develop a digital elevation model (DEM) of Weno which was used to determine the elevations for the pipe junctions in the model.

The Weno Island Master PLAN (FSM/UN Water Resources Assessment and Development Project, 1993) proved to be a valuable source of information about the physical characteristics of the Weno water system. Information on the location, diameter and material was provided for the pipes in the system. Tank sizes and elevations were provided along with the location of wells and their characteristics as well as pumps sizes for the wells that existed at that time. Estimates of consumer water demands were also available in the report.

WERI researchers spend a week on WENO working with the CPUC staff in order to be sure that the system maps were accurately drawn and that the system component were properly characterized. CPUC staff also provided information on the locations and consumption rate of the high use customers in the system. The CPUC's staff was also invaluable in identifying system operation and updating all the system description information to present day conditions. At the request of the CPUC the water model was split into water delivery zones. These zones were identified by the CPUC and are shown in Figure 1.

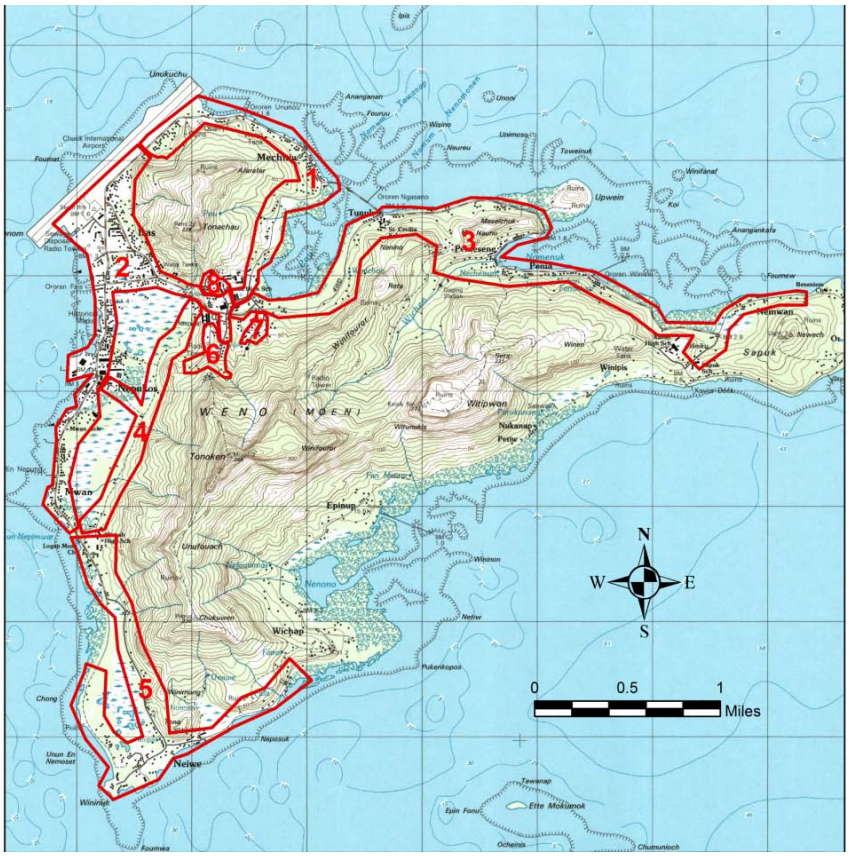


Figure 1. Water delivery zones, Weno water system

Phase II. Develop a Hydraulic Network Model of the CPUC Water Transmission System

Phase II involved the development of a hydraulic network model of the CPUC system using the hydraulic modeling program EPANET. This public domain (and at no cost) program was developed by the US Environmental Protection Agency (EPA) and is available on the EPA web site http://www.epa.gov/nrmrl/wswrd/dw/epanet.html The model has been used worldwide to simulate water distribution systems.

The model is relatively easy to use and yet very sophisticated. It can be used to model systems from the very simple to the very complex looped piping systems. It has the capability to do time simulations and therefore can model a system over days months or even years.

By using what is called patterns the model is able to change customers' demands in order to simulate real time changing use rates in a real world environment. The model can also simulate changing water quality parameters throughout a water system, although we did not implement these capabilities in the Weno model. This capability could be easily adopted in the future since the basic hydraulic model will already be in place. Although there are more sophisticated and more costly water system modeling programs, this program will be able to provide CPUC with all the computational capabilities required for them to analyze and hopefully improve the operation of their system. Another plus for the program is the capability of other modeling programs to read the input files

created by EPANET. Therefore, in the future, if CPUC should decide to move up to a more sophisticated model the time and expense invested in the developing the EPANET model will not be lost. The data gathered in Phase I of the study was then input to the model. Figure 2 shows the entire water system network map for the Weno system.

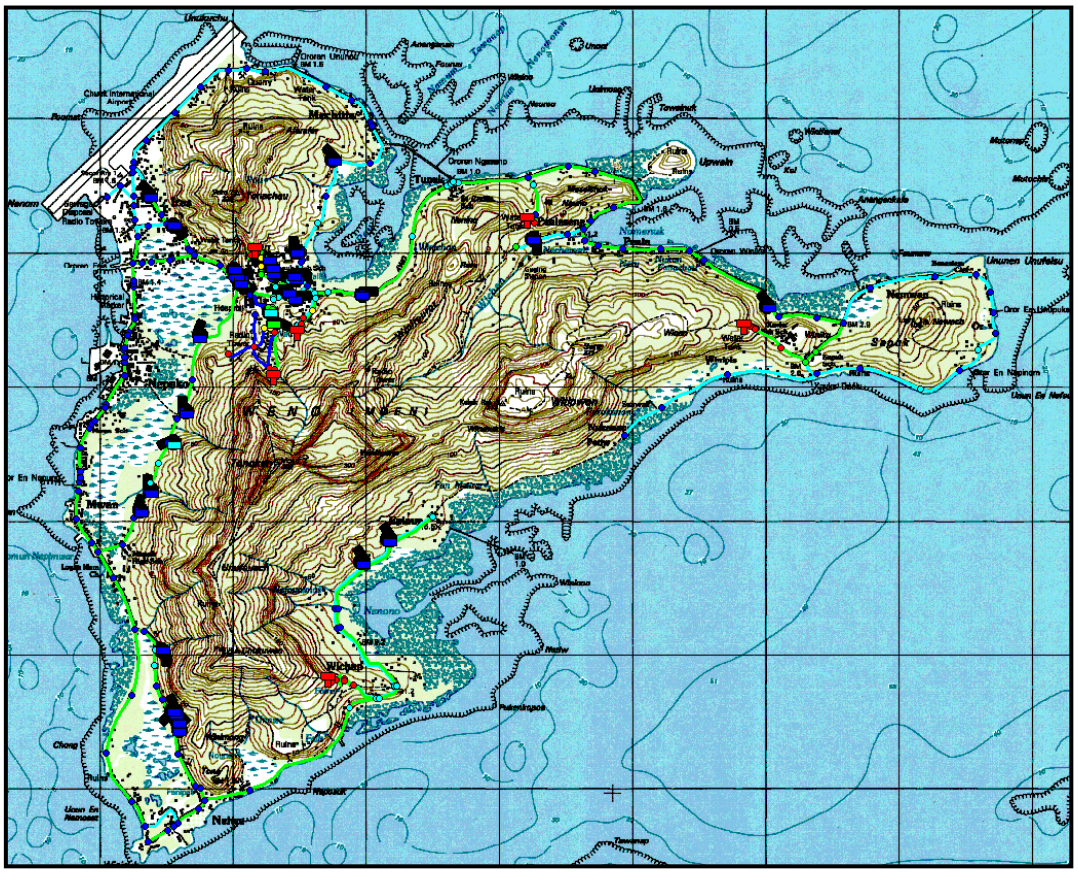


Figure 2. Entire EPANET water system network map for the Weno system

Input Data for EPANET model

The next major effort came in assigning demands to the junction nodes where users require the delivery of water. A spreadsheet workbook was developed to do all the water use rate calculations. We began first with the higher use rate customers. CPUC provide data on the location and characteristics of the high use customers. Table 1 shows a summary of the rates used by various classes of high rate user. Based on number of students, people in each apartment (CPUC assumption), and number of beds in each hotel, we calculated the actual use values that were assigned to the high user junctions. A junction was located in the water system model for each of the high users and the computed value for that user was assigned as the base demand for that junction.

USE RATES FROM CHUUK MASTER PLAN REPORT		
TYPE OF USE	AMOUNT	UNITS
DOMESTIC APARTMENTS	50	GAL/DAY/PERSON
HOTEL	175	GAL/BED
ICE PLANT	1000	GAL/DAY
LAUNDRY	1500	GAL/DAY
BIG COMMERCIAL SHOPS	800	GAL/DAY
SMALL SHOPS	300	GA/DAY
RESTURANT	700	GAL/DAY
SCHOOL WITH DORM	100	GAL/DAY/STUDENT
HOSPITAL	360	GAL/BED/DAY
SCHOOL WITH CAFETERIA	12	GAL/DAY/STUDENT

Table 1. Generalized use rates used for high use rate customers

The Weno water delivery system was divided into 8 water delivery zones as shown in Figure 1. These zones were determined by the CPUC based on operational constraints of the system. The CPUC determined the number of residential dwelling in each of the zones. These served as basic input to the calculations that resulted in the demand per junction that served as input to the hydraulic models that were developed. The other input parameters included the number of people residing in each residence and the water consumption rate per person. The final values used were 8 people per residence and 50 gallons per capita per day. These values were kept as variables to add flexibility to the spreadsheet so that we could explore other use rate combinations. The values in demand per junction column were then transferred to the EPANET model of the Weno system. All the residential junctions in the same zone were assigned the same base demand as determined on the spreadsheet for that zone.

The Weno system is largely supplied by well pumps so it is very important that the hydraulic description of each of the pumps stations is accurately described. Some of the description information was obtained by field visits by WERI investigators, but the majority of the information was supplied directly by CPUC. Other important parameters were ground elevation at the well heads, location of the pump in the well, static water elevation, pumping drawdown, storage tanks, and a description of the piping system from the pump to the distribution system main. This information was supplied by CPUC and site visitation and was transferred to the EPANET model.

Patterns of demand use changes during the day were developed in order that time simulations could be run using the EPANET model. These patterns provide a multiplying factor (to be multiplied by the average base flow) in order to get the correct flow value for a particular time interval. We are presently performing a study in Saipan where we are actually using digital water meters to refine these water use pattern estimates. As data from this study becomes available it can be easily added to the Weno water system model.

Development of an alternative water system model

After developing the input files for the EPANET model the model was run to verify that all components of the system were being modeled correctly. We noticed during this

verification process that the total hydraulic head was different in each of the water division zones shown in Figure 1, but this total head remained relatively constant throughout each of the zones. Upon further inspection we could see that because of the relatively large size of the distribution system mains the friction losses in the mains were very small throughout the zones. Because of this the total head in the distribution system within a zone remained relatively constant. This led us to believe that we might be able to develop a somewhat simpler hydraulic model than the EPANET model for the Weno system. While this model would not be able to compute exact pressures and flows throughout the system, it would be able to compute pump flows for various system demands. Secondly we could base this simple model on a spreadsheet application which would greatly simplify the input of hydraulic and demand values over that required when using the EPANET program.

The model is set up in the same workbook that is used to maintain the parameters for the EPANET model therefore it is easy to keep both models updated with the same parameters. The spreadsheet model runs in a separate spreadsheet in the workbook, and most of the computations are done in a set of Microsoft Visual Basic macros that were designed for the relatively hydraulically simple Weno system. Detail on computation procedure is reported in (Heitz, Khosrowpanah, 2013)

Model Calibration

Both the complete EPANET model and the spreadsheet model were run several times in order to insure that all components were properly sized and described. This "calibration" process uncovered some short comings in the existing data available to the modelers. One critical parameter for the model is the elevation of the water in the well while the pump is in operation. The elevation is calculated from data provided by the CPUC operators. They physically measure the distance from the well head to the pumping water level. This parameter is usually fairly easy to obtain. The second parameter needed to get this well water elevation is the ground elevation at the well head. This parameter needs to be fairly accurate since it is used to set the pumping water elevation which is used to determine the distribution of water deliveries for each pump in a particular water delivery zone. If either the depth to water or well head elevation is in error, then the delivery predicted by the models will be in error. We were never able to get a complete listing of all of accurate well head elevations.

Because of the separate nature of the water delivery zones, the wells in each zone will attempt to deliver the input demands for that zone. It is recognized that there is a certain degree of water loss in all parts of the system, but it is unknown exactly how much that loss is at this time. Again in order to calibrate the model to the existing conditions it is important to have a firm grasp of the customer use rates and losses.
We tried several different loss rates and were able to come close to the measured pump rate, but more work needs to be accomplished on this issue.

What is needed now is to accurately measure the elevations of each of the well heads and recheck all of the depths to water while pumping. When these two variables are confirmed, the "calibration" process can then be continued until reasonable use and loss

rates are obtained. In the future as leak detection and repair studies are made then the model will need adjustments to match the improvements that are made.

Phase III. Development of a GIS database of the water system resources

Using the data developed in Phases I and II, GIS maps and databases describing PUC's water system were developed. The GIS database developed consists of the physical location descriptions of the pumps, pipes, tanks, and valves in the system. System component attributes included parameters such as size, pipe length and diameter, materials, and connectivity to other components of the system. Parameters such as date of installation and condition of the component can be added at a later date wherever available. Most of the data for the GIS was obtained through exportation of the EPANET water system model data. This was accomplished by first inputting the EPANET data files into the Haestad Water system modeling software. The Haestad model has a means of directly exporting the water system component data to ARCGIS shape files. Figure 3 shows the ARCGIS program with the basic system components visible. A sample of the kind of data that is included in the database is shown in Figure 4. In this case we have joined portions of the input data worksheets described previously to the attribute table for the pump shape file. Maintenance items such as when scheduled maintenance is required could easily be added to the data base.

Principal Findings and Significance

A complete water system hydraulic model and GIS database of water system components was developed for the Weno Island water system in Chuuk State, Federated States of Micronesia.

The hydraulic model is running well but requires further calibration because of lack of accurate well head elevations and depths to water in the wells while the pumps are operating. These inadequacies should be remedied to insure accurate model calibration.

A second area of concern is with the estimates of customer water use and loss rates within the piping system. Spot checking of metered usage and number of residents served by meters would be helpful in getting more accurate estimates for the model. Probably even more important to model calibration is estimating losses because of leakage in the system. The model can easily account for losses as a percentage of total delivery but the loss rates used thus far are fairly crude estimates. As time goes by and leak detection studies are carried out hopefully better loss rate values will be available and these loss rates will be reduced over time.

Literature Cited

Heitz, L. F. "Development of a Computerized Distribution System Model of the Moen Island Water Distribution System", Report No. 62, University of Guam, Water and Energy Research Institute, January 1986.

FSM/UN Water Resources Assessment & Development Project, 1993, "Weno Island Master Plan", Water Supply Development 1993-2002.

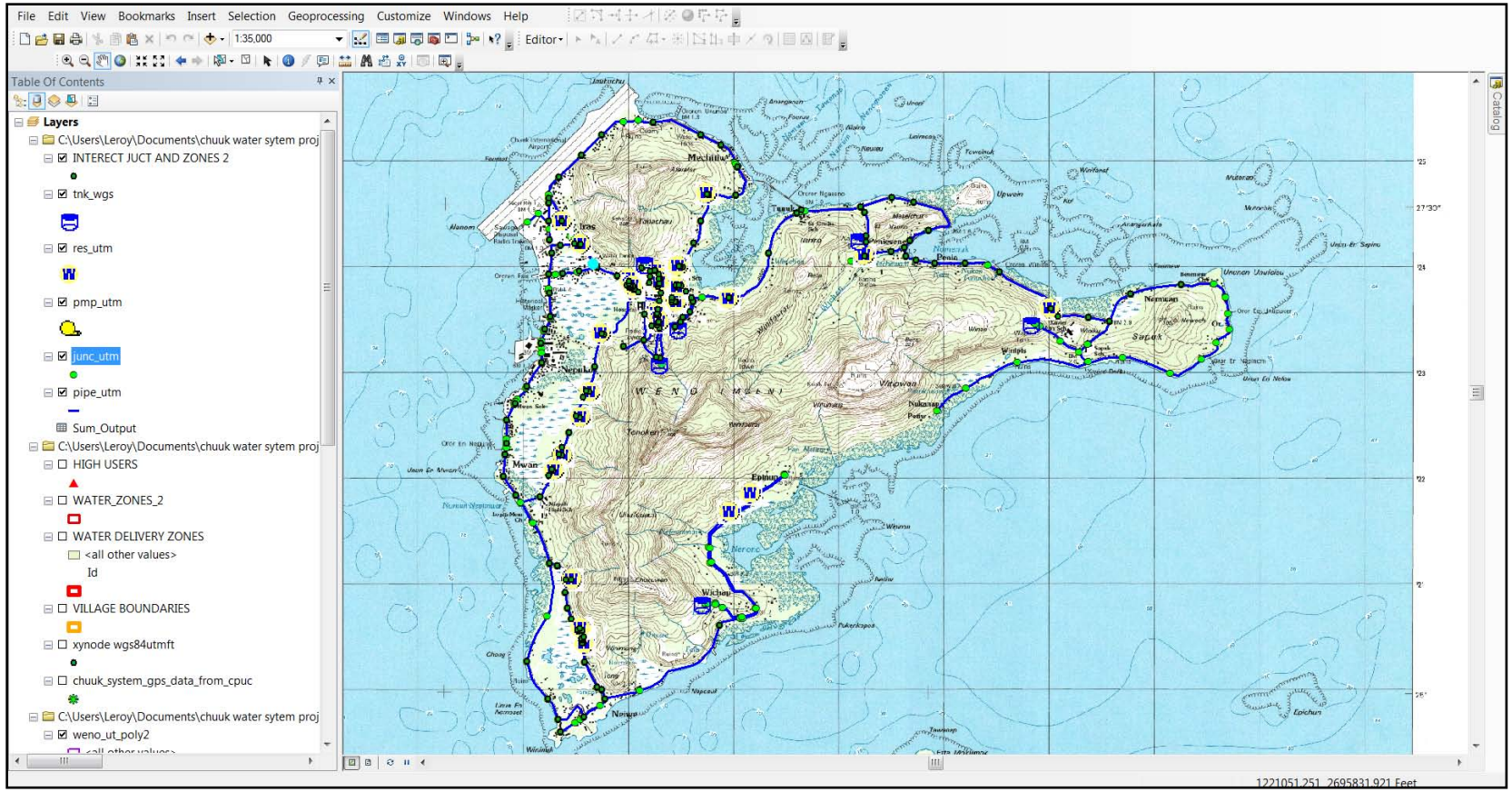
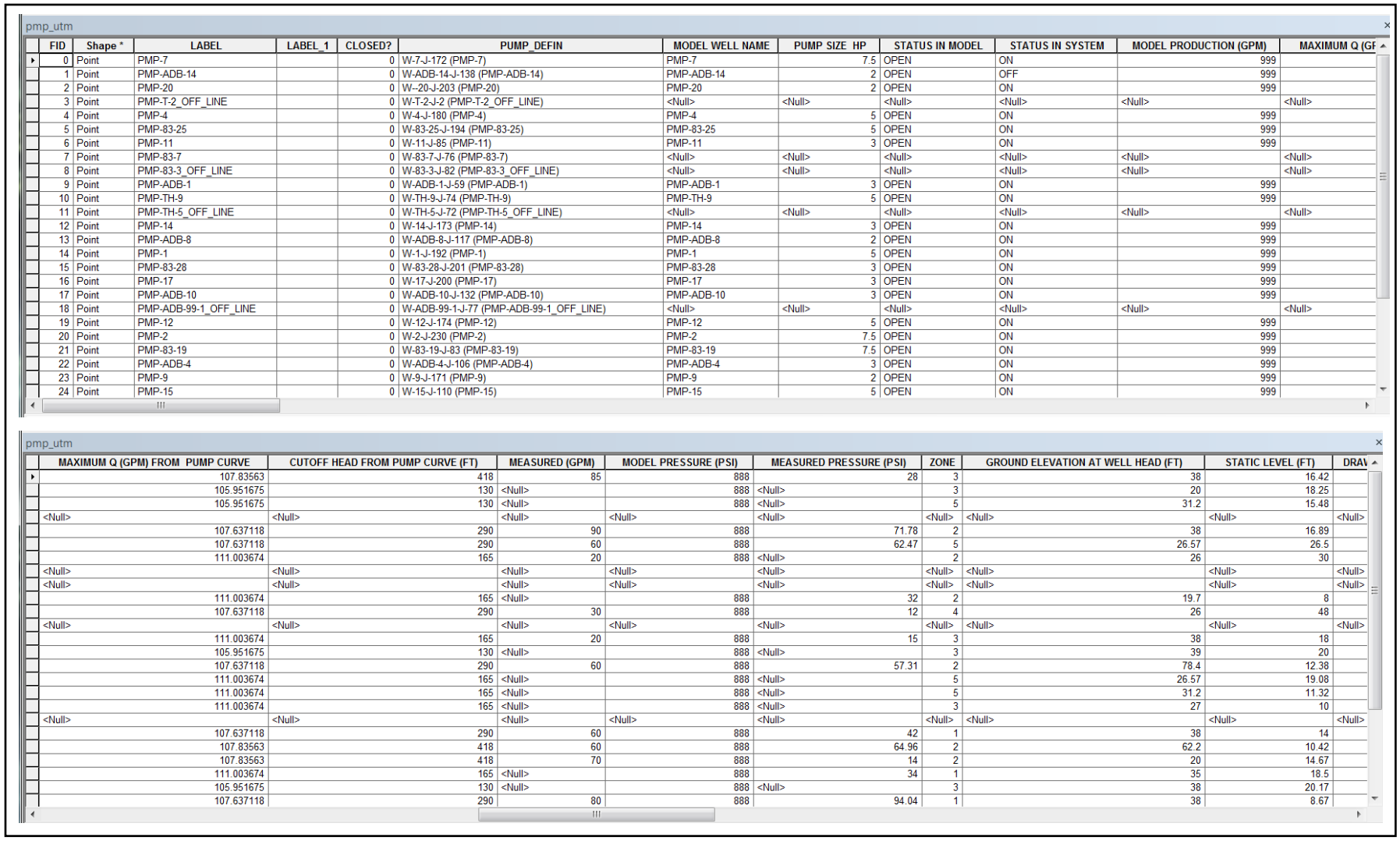


Figure 3. ARCVIEW GIS program showing the basic components of the Weno water system



pmp_utm

FID	Shape *	LABEL	LABEL_1	CLOSED?	PUMP_DEFIN	MODEL WELL NAME	PUMP SIZE HP	STATUS IN MODEL	STATUS IN SYSTEM	MODEL PRODUCTION (GPM)	MAXIMUM Q (GP
0	Point	PMP-7		0	W-7-J-172 (PMP-7)	PMP-7	7.5	OPEN	ON	999	
1	Point	PMP-ADB-14		0	W-ADB-14-J-138 (PMP-ADB-14)	PMP-ADB-14	2	OPEN	OFF	999	
2	Point	PMP-20		0	W--20-J-203 (PMP-20)	PMP-20	2	OPEN	ON	999	
3	Point	PMP-T-2_OFF_LINE		0	W-T-2-J-2 (PMP-T-2_OFF_LINE)	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
4	Point	PMP-4		0	W-4-J-180 (PMP-4)	PMP-4	5	OPEN	ON	999	
5	Point	PMP-83-25		0	W-83-25-J-194 (PMP-83-25)	PMP-83-25	5	OPEN	ON	999	
6	Point	PMP-11		0	W-11-J-85 (PMP-11)	PMP-11	3	OPEN	ON	999	
7	Point	PMP-83-7		0	W-83-7-J-76 (PMP-83-7)	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
8	Point	PMP-83-3_OFF_LINE		0	W-83-3-J-82 (PMP-83-3_OFF_LINE)	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
9	Point	PMP-ADB-1		0	W-ADB-1-J-59 (PMP-ADB-1)	PMP-ADB-1	3	OPEN	ON	999	
10	Point	PMP-TH-9		0	W-TH-9-J-74 (PMP-TH-9)	PMP-TH-9	5	OPEN	ON	999	
11	Point	PMP-TH-5_OFF_LINE		0	W-TH-5-J-72 (PMP-TH-5_OFF_LINE)	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
12	Point	PMP-14		0	W-14-J-173 (PMP-14)	PMP-14	3	OPEN	ON	999	
13	Point	PMP-ADB-8		0	W-ADB-8-J-117 (PMP-ADB-8)	PMP-ADB-8	2	OPEN	ON	999	
14	Point	PMP-1		0	W-1-J-192 (PMP-1)	PMP-1	5	OPEN	ON	999	
15	Point	PMP-83-28		0	W-83-28-J-201 (PMP-83-28)	PMP-83-28	3	OPEN	ON	999	
16	Point	PMP-17		0	W-17-J-200 (PMP-17)	PMP-17	3	OPEN	ON	999	
17	Point	PMP-ADB-10		0	W-ADB-10-J-132 (PMP-ADB-10)	PMP-ADB-10	3	OPEN	ON	999	
18	Point	PMP-ADB-99-1_OFF_LINE		0	W-ADB-99-1-J-77 (PMP-ADB-99-1_OFF_LINE)	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
19	Point	PMP-12		0	W-12-J-174 (PMP-12)	PMP-12	5	OPEN	ON	999	
20	Point	PMP-2		0	W-2-J-230 (PMP-2)	PMP-2	7.5	OPEN	ON	999	
21	Point	PMP-83-19		0	W-83-19-J-83 (PMP-83-19)	PMP-83-19	7.5	OPEN	ON	999	
22	Point	PMP-ADB-4		0	W-ADB-4-J-106 (PMP-ADB-4)	PMP-ADB-4	3	OPEN	ON	999	
23	Point	PMP-9		0	W-9-J-171 (PMP-9)	PMP-9	2	OPEN	ON	999	
24	Point	PMP-15		0	W-15-J-110 (PMP-15)	PMP-15	5	OPEN	ON	999	

pmp_utm

MAXIMUM Q (GPM) FROM PUMP CURVE	CUTOFF HEAD FROM PUMP CURVE (FT)	MEASURED (GPM)	MODEL PRESSURE (PSI)	MEASURED PRESSURE (PSI)	ZONE	GROUND ELEVATION AT WELL HEAD (FT)	STATIC LEVEL (FT)	DRAV
107.83563	418	85	888	28	3	38	16.42	
105.951675	130	<Null>	888	<Null>	3	20	18.25	
105.951675	130	<Null>	888	<Null>	5	31.2	15.48	
<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
107.637118	290	90	888	71.78	2	38	16.89	
107.637118	290	60	888	62.47	5	26.57	26.5	
111.003674	165	20	888	<Null>	2	26	30	
<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
111.003674	165	<Null>	888	32	2	19.7	8	
107.637118	290	30	888	12	4	26	48	
<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
111.003674	165	20	888	15	3	38	18	
105.951675	130	<Null>	888	<Null>	3	39	20	
107.637118	290	60	888	57.31	2	78.4	12.38	
111.003674	165	<Null>	888	<Null>	5	26.57	19.08	
111.003674	165	<Null>	888	<Null>	5	31.2	11.32	
111.003674	165	<Null>	888	<Null>	3	27	10	
<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
107.637118	290	60	888	42	1	38	14	
107.83563	418	60	888	64.96	2	62.2	10.42	
107.83563	418	70	888	14	2	20	14.67	
111.003674	165	<Null>	888	34	1	35	18.5	
105.951675	130	<Null>	888	<Null>	3	38	20.17	
107.637118	290	80	888	94.04	1	38	8.67	

Figure 4. Sample of a portion of the pump attribute table for the Weno water system GIS

Information Transfer Program Introduction

WERI's research activities focus predominantly on local water resources problems and issues identified largely through discussions with regional stakeholders at our annual advisory council meetings. Disseminating the results of these investigations to appropriate governmental agencies, environmental managers, policy makers and other local decision makers in the water resources business, has the highest priority and is accomplished in various ways. Institutional technical reports remain a strong vehicle for transmitting such information to our target audiences, many of whom are remotely situated and do not have access to the scientific literature, or require a greater degree of detail than is normally permissible in a standard journal publication. WERI faculty have also become increasingly more interactive with audiences overseas in recent years by sharing their research findings at professional meetings, conferences and workshops at the national and international level. Our recently improved website is gaining increased popularity among professional circles, both at home and abroad, and is now accessible to the great majority of our stakeholders throughout the region. Our annual Advisory Council meetings in Guam, the CNMI and the FSM are highly effective information transfer mechanisms, bringing together people who typically have little to no contact with one another during the rest of the year. These meeting serve as a valuable forum of information exchange and discussion on common issues, problems and needs in the water resources arena. We remain strong in our commitment to teaching and training the up-and-coming water resources professionals of tomorrow, in addition to conducting workshops, courses and seminars for those currently employed in this area. WERI faculty also continue to be major and effective participants in water related law and policy making on Guam by serving as committee members and chairs on numerous governmental boards and by giving testimony at legislative oversight hearings.

Information Transfer

Basic Information

Title:	Information Transfer
Project Number:	2012GU215B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	N/A
Research Category:	Not Applicable
Focus Category:	Education, Management and Planning, Water Supply
Descriptors:	Information Transfer, Education, Water Resources
Principal Investigators:	Gary Denton

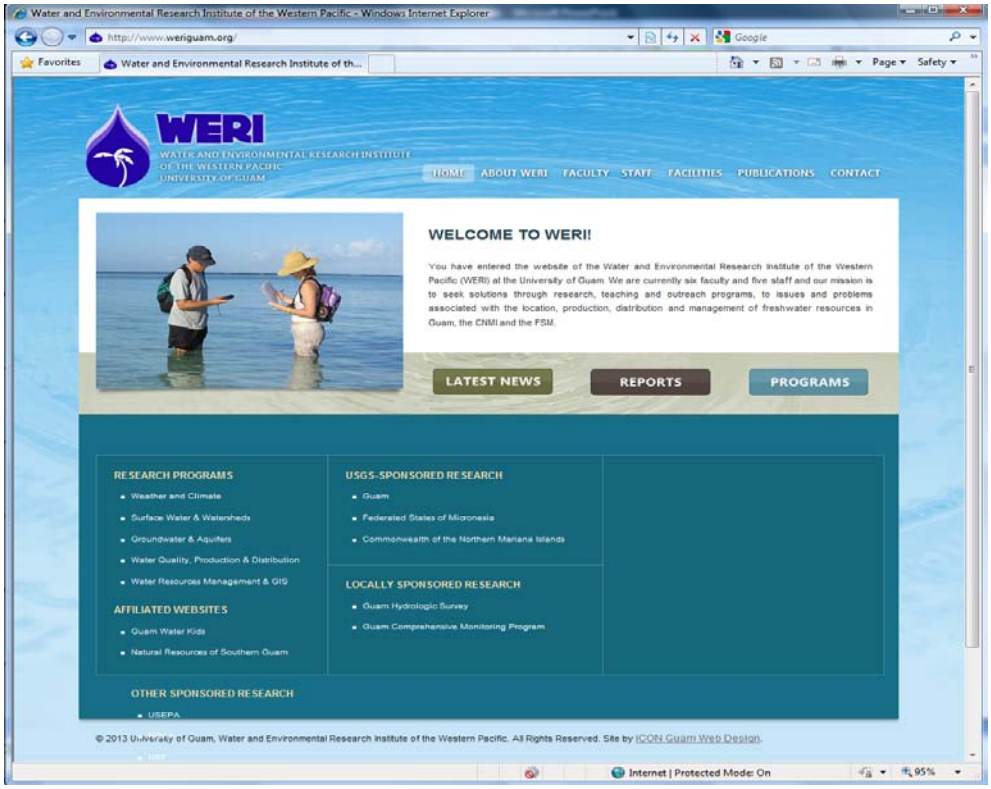
Publications

There are no publications.

PROJECT SYNOPSIS REPORT

WERI's mission involves a large information transfer-dissemination component. Key elements include written forms such as brochures and pamphlets, a web site, technical reports, journal articles, newspaper columns, and book chapters. The audience for the results of USGS sponsored research is widely varied geographically and by education level. It is important that WERI make this information available in a very widely distributed form.

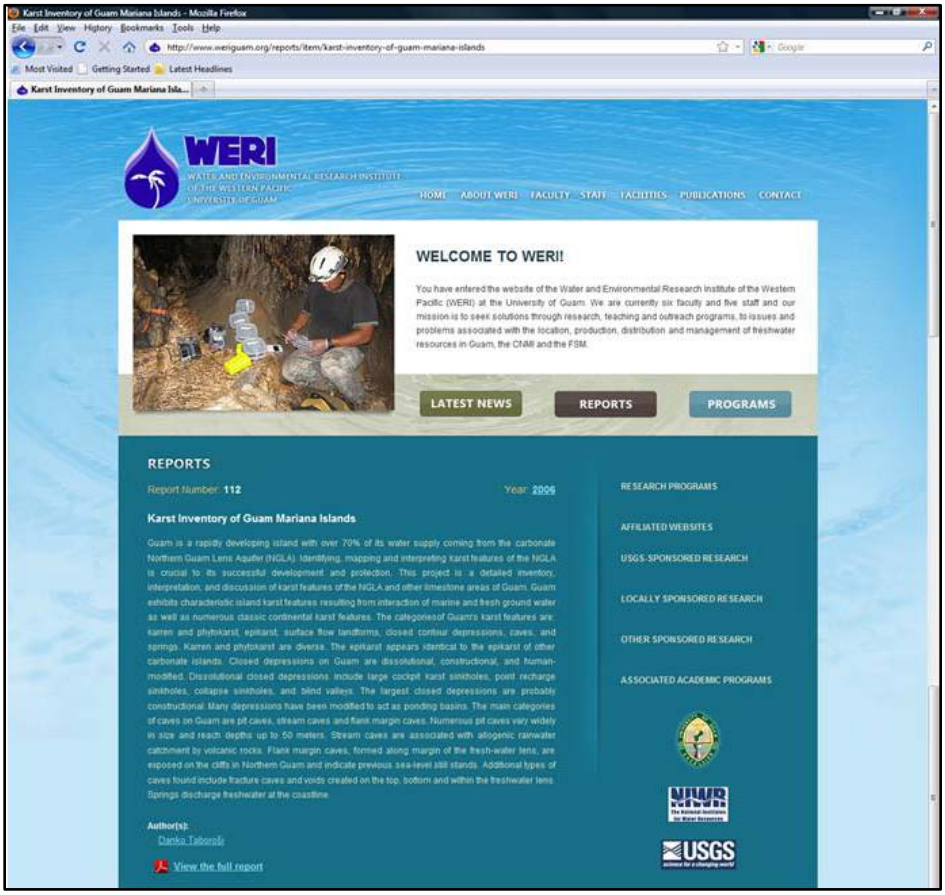
The WERI web-site is the Institute's primary Information Transfer/Dissemination mechanism. The home page, shown below, is located at http://www.weriguam.org/. It features informational links to WERI faculty, staff and Institutional facilities, our current research, education and training activities, primary sponsors and most recent publications. The user friendly format is intended to increase visibility of the Institute's research programs and associated projects particularly for our stakeholders in remote locations where state-of-the-art internet services and computer technology are often lacking.



WERI Web-site Home Page

This project also funded the design, layout and printing of five (5) major technical completion reports resulting from USGS funded research projects. Fifty (50) hard copies of each report were printed. All WERI technical completion reports are available in downloadable pdf format on the WERI web-site at http://www.weriguam.org/reports/list.

The technical completion report library was updated with several new additions bringing the total number of available volumes to 141. The improved database search engine process for accessing these reports on line utilizes a composite 'Abstract' database for key word searches. Searches based on 'Author' now search all authors in the author string not just the lead author as before. Upon selection of a particular report, site users are presented with the complete abstract, which may be viewed prior to downloading the main report. An example is shown below.



WERI Reports Page

Because of Guam's remote location, and the escalating costs of air travel, it is difficult and costly for researchers to present their findings at technical conferences and symposiums in other parts of the Globe. A portion of the current Information Transfer Project was earmarked for off-Island travel expenses for PI's and graduate students presenting refereed professional papers summarizing all or a portion of current or past USGS 104-B projects.

Teaching Teachers about Guam's Water Resources and 'Guam Water Kids': 1 Credit Hour Continuing Education Course with Guam Department of Education, Professional & International Program-University of Guam, and WERI

Basic Information

Title:	Teaching Teachers about Guam's Water Resources and 'Guam Water Kids': 1 Credit Hour Continuing Education Course with Guam Department of Education, Professional & International Program-University of Guam, and WERI
Project Number:	2012GU216B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	N/A
Research Category:	Not Applicable
Focus Category:	Education, Non Point Pollution, Conservation
Descriptors:	Water resources, teacher training, aquifer, groundwater, surface water, watershed, Guam, hydrological cycle, ground water, non-source pollution, non-point pollution, conservation, fresh water, water supply, education
Principal Investigators:	Arretta Ann Card

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

Project Title: Teaching Teachers about Guam's Water Resources and 'Guam Water Kids': 1 Credit Hour Continuing Education Course with Guam Department of Education, Professional & International Program-University of Guam, and WERI

Problem and Research Objectives

The WERI Advisory Council for Guam identified two critical water resources needs for research, education and training: (1) the development of a teacher training course about water resources and (2) educational training and outreach programs about the importance of protecting and preserving watersheds and water resource. The council specifically advised beginning with “elementary schools in order to instill the importance of these issues at a young age”.

With assistance from WERI, 104-B WRRI and the USGS, environmental educational materials addressing local water resources and related issues were developed under previous grants. These materials were developed for students age 9-12 and packaged in a "kid friendly" format called "Guam Water Kids" in 2009. The materials consist of a narrated presentation suitable for classroom use, two lesson plans, a Chamorro glossary of related terms, and a companion website featuring maps, illustrations, and photos of life and people on Guam. These materials were subsequently demonstrated at onsite visits in Guam classrooms include public, Department of Defense, and private schools in 2010 and 2011.

In follow up surveys, teachers who viewed the demonstration with their students characterized components of "Guam Water Kids" as extremely effective and appropriate for that age level, but indicated they were unsure whether they expected to use the materials on their own in the future. Further discussions with participating educators indicated that teachers needed more exposure to the fresh water topics covered in “Guam Water Kids” materials.

Under this grand, a continuing education course was developed in summer 2012 and offered at through University of Guam’s Professional International Program (PIP) in fall 2012 semester to address this need. The objective of the course was to provide classroom teachers on Guam the opportunity to become fully prepared to integrate fresh water basics into their yearly teaching plans using "Guam Water Kids" materials and developing expanded learning experiences for their students.

Methodology

Teaching Teachers About Guam's Fresh Water and 'Guam Water Kids,' a one-credit hour continuing education course, followed the outline of the "Guam Water Kids" class presentation offering detailed, in depth information for course participants. Topics include the value of fresh water to life on Guam; the Water Cycle emphasizing infiltration and collection related to specifics of Guam's geological features; surface water and ground water on Guam; the impact of the population center above the Northern Guam Lens Aquifer, and the impact of agricultural, recreational activities and weathering

on the Ugum Watershed. The course was developed by Ann Card, former faculty member at the University of Guam, and Jennifer Berry, elementary educator. The course was offered in October 20-November 10 for 15 hours of instruction. The course utilized related readings, guest demonstrations by professionals in the field, and activities. Instruction emphasized a problem-solving approach that required course participants to present "Guam Water Kids" in their respective classrooms and to adapt course resources to expand learning opportunities appropriate to their teaching assignments.

The Guam Department of Education and the Department of Defense assisted with the recruitment of course participants by sending a recruitment flyer to all teachers and principals in the public system (Fig. 1). Because of the assistance of WERI and the USGS, course participants were required to pay only a small fee of $20 to absorb UOG-PIP administrative costs. All materials were provided as handouts or online at no additional cost to participants.

Principal Findings and Significance

Fifteen contact hours of class presentations, activities and demonstrations were developed and delivered. Training in the use Guam Water Kids materials and accompanying lesson plans centered motivating students by focusing on "action learning" experiences.

Topics from guest presentors included: Masso watershed, fresh water species of Guam, sling stone tree planting and the how one teacher created a "take action" project that is now institutionalized islandwide. (Fig. 3) In addition, class participants were oriented to the WERI website with emphasis on the Natural Resource Atlas of Southern Guam and the U.S. Geological Survey website with emphasis on Education section and a sample selection from the the USGS's catalog of budget-friendly educational materials.

During the course, all participants demonstrated the ability to use "Guam Water Kid"s as a teaching tool in their classrooms by presenting the materials on their own and further designing and delivering a hands-on activity expand and re-enforce the two lesson plans provided (Fig. 2). The teachers who took the course assembled a "teacher's resource binder" including copies of "Guam Water Kids" materials plus their personal course notes, results of their research and assignments, handouts and their own photos. These binders were a required assignment and intended to become a permanent resource their personal libraries. In addition, each teacher produced a static display with the participation of own students featuring an activity related to fresh water issues.

The initial offering of the course was successfully completed by 15 educators including elementary, middle and high school teachers from public, private and Department of Defense schools. (Fig. 4)

UNIVERSITY OF GUAM
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Administration & Finance
Professional & International Programs

Programs

1 Hour: Graduate Credit or Continuing Education Credit At University of Guam

Teaching Teachers about Guam's Fresh Water and 'Guam Water Kids'

COURSE FOCUSES on the value of fresh water as a natural resource and related earth science background with **emphasis on Guam features and conditions** and information about **what kids can do** to take responsibility for avoiding pollution and waste. Demonstrates **classroom activities and ideas** including use of *'Guam Water Kids,'* a free program approved for use in GDoE and DoDEA

WHO SHOULD TAKE THIS CLASS? All teachers and others working with elementary and middle school students. *Applicable to Science, Earth Science, Ecology, Language Arts, Social Studies, Chamorro Studies,, and Art, Life Skills, Service Learning and Career Education.* **Class size will be limited to 25.**

INSTRUCTORS Jennifer Berry, Ann Card

WHERE & WHEN? University of Guam campus on four Saturdays:
October 20, 8:30-12:30 **November 3, 8:30-12:30**
October 27, 8:30-12:30 **November 10, 8:30-11:30**

COST A $20 recording fee will be charged.

'Guam Water Kids' and this continuing education course made possible by WERI: The Water and Environmental Research Institute of the Western Pacific, UOG, with funding assistance from the U.S. Geological Survey.

FOR INFORMATION AND ENROLLMENT, please contact Instructor Jennifer Berry at 483-6161 or 472-2466 or email jberry2466@gmail.com.

ENROLL NOW ... class size is limited.

UOG Station, Mangilao, Guam 96923
Telephone: +1 (671) 735-2600/1 | Fax: +1 (671) 734-1233

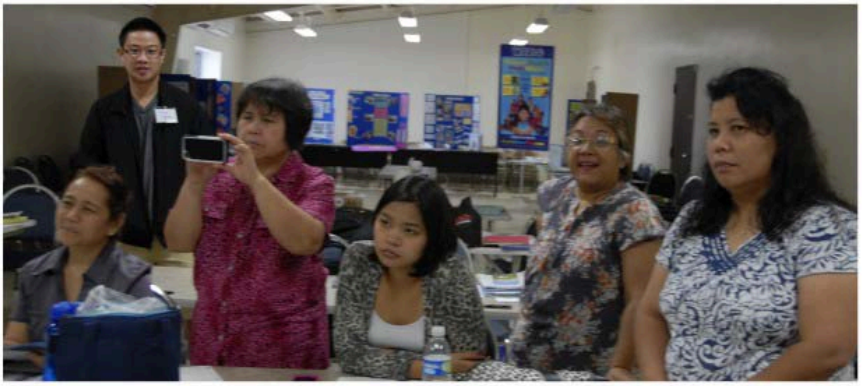
Figure 1. Recruitment flyer.

Fall 2012 Participants

Figure 2. Each teacher produced a static display with the participation of their own students featuring one of their own activities related to fresh water.

Brent Tibbatts, Guam Deptartment of Aquatic and Wildlife Resources

Tammy Jo Anderson Taft, Guam Environmental Protection Agency



Course participants learn more about fresh water issues from local professionals

Figure 3. Course participants.

Figure 4. Fifteen Guam educators became "Guam Water Kids Teachers," by completing the graduate credit course.

One-Day Executive/Professional Field Course, with Webpage on Sustainable Management of the Northern Guam Lens Aquifer

Basic Information

Title:	One-Day Executive/Professional Field Course, with Webpage on Sustainable Management of the Northern Guam Lens Aquifer
Project Number:	2012GU217B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	N/A
Research Category:	Not Applicable
Focus Category:	Education, Groundwater, Management and Planning
Descriptors:	Groundwater education, Aquifer field trip, Aquifer models
Principal Investigators:	John Jenson

Publication

1. Danko Taboro¨i and John W. Jenson, 2013, Executive Field Trip Guide to the Northern Guam Lens Aquifer, Water & Environmental Research Institute of the Western Pacific, Island Research & Education Initiative, 29 pages.

PROJECT SYNOPSIS REPORT

Project Title: One-Day Executive/Professional Field Course, with Webpage on Sustainable Management of the Northern Guam Lens Aquifer

Problem and Research Objectives

The planned military buildup and associated economic growth anticipated on Guam over the next decade has raised concerns regarding sustainable management of Guam's groundwater resources. To arrive at appropriate policy, regulations, and management practices and obtain public support it is essential that policy-makers, water resource professionals, and island educators be equipped with an accurate and up-to-date understanding of the essential characteristics of the island's aquifer and the factors that must be considered to frame and implement sustainable management practices. A universal challenge, however, is that policy-makers, community leaders and other professional people have extremely limited time to engage in instructional opportunities.

Methodology

We developed and delivered and executive field course for senior policy-makers and agency heads consisting of (1) a single day of intensive personal instruction delivered in the field, with (2) a binder of materials and a supporting webpage containing the instructional materials and links to external resources. Dr. Jenson (field instructor) developed the course content and field trip itinerary. Dr. Taboroši (course material editor) designed and developed a 29-page field guild supported by web-based resources. On the days of field trips, Dr. Jenson rode with the participants in a 14-passenger van, delivering instruction at not only the four selected stops, but during the time between stops. The field course was presented on two consecutive days (11 and 12 April 2013).

Principal Findings and Significance

Those invited for the first day included the top-level senior leaders: the Governor of Guam, Commander Joint Region Marianas, Commander 36th Air Base Wing, Chairman of the Guam Consolidated Commission on Utilities, and consuls-general from consulates on Guam. Invited for the second day were the agency heads of the Guam Waterworks Authority, Guam Environmental Protection Agency, chairs of the legislative committees with oversight on water and environmental interests, etc. Interest and participation were excellent; the principal members invited either attended or sent their deputy or a senior member of their staff. During the field trips, participants were shown the basement rock that underlies and forms the hydrologic boundary of the aquifer, a large quarry in which the aquifer rock is well exposed, a sinkhole in which rapid entry of water can be observed, and the summit of the highest hill above the aquifer from which the entire catchment can be observed. Between stops, Dr. Jenson delivered instruction from the field guide concerning the basic aspects of aquifer geology, hydrology, and management. The course was well received and has prompted requests from local agencies, engineering professionals, and educators for future offerings.

Presenting 'CNMI Water Kids': Private Elementary/Middle Schools and Northern Marianas College of Education Outreach/Teacher Relations Program

Basic Information

Title:	Presenting 'CNMI Water Kids': Private Elementary/Middle Schools and Northern Marianas College of Education Outreach/Teacher Relations Program
Project Number:	2012GU220B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	N/A
Research Category:	Not Applicable
Focus Category:	Education, Non Point Pollution, Conservation
Descriptors:	Water resources, aquifer, groundwater, surface water, watershed, CNMI, water cycle, ground water, non-source pollution, non-point pollution, conservation, Mariana Islands, limestone
Principal Investigators:	Arretta Ann Card

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

Project Title: Presenting 'CNMI Water Kids': Private Elementary/Middle Schools and Northern Marianas College of Education Outreach/Teacher Relations Program

Problem and Research Objectives

Environmental educational materials addressing water resource issues in a context familiar to Commonwealth of the Northern Mariana Islands (CNMI) children and educators were developed with the support of a grant from WERI, 104-B WRRI and the USGS. The educational materials and accompanying illustrations and images address basic features of the fresh water resources on the Northern Mariana Islands of Saipan, Tinian, Rota, at a level appropriate for students aged 9-12. The island's critical need to protect and conserve their fresh water resources was developed and packaged in a "kid friendly" and "teacher friendly" format called "CNMI Water Kids". These materials include a multimedia presentation, teacher lesson plans and other accompanying materials, and a companion website.

In previous year, the "CNMI Water Kids" was offered to 6th graders and their teachers at all CNMI Public Schools. Commissioner of Education of the CNMI PSS, Dr. Rita Sablan, lent enthusiatic approval and the invaluable support of her staff to assist in scheduling school visits. Thirteen team presentations at the 12 public elementary schools on the three islands were made.

This year goals were to continue the school visitations to engage both students and educators at *private* schools in the CNMI, conduct a workshop or class presentation to education majors at the CNMI School of Education in the Northern Marianas College, and identify a plan for offering CNMI elementary and junior teachers a 1 credit hour continuing education course in water resources as a collaborative effort with the CNMI in Saipan.

Nine team presentations were made at private schools and two workshops were offered at the College of the Northern Marianas. In addition, a means of offering CNMI elementary and junior high teachers a continuing education course in water resources as a collaborative effort with the CNMI PSS was explored.

Methodology

The presentations were designed to introduce and demonstrate materials developed in the "CNMI Water Kids" to the teachers and students at CNMI private schools. Students and their teachers had the opportunity to see the narrated multi-media presentation and discuss the contents in team presentations conducted by Ann Card and Jennifer Berry. The presentations focus on the basic concepts of the importance of fresh water in daily life with emphasis on the water cycle and how it sustains surface and ground water resources on their own islands.

During the site visits, the team discussed the resource materials with each teacher in attendance and if possible the school librarian and language teacher. Each school retained a CD and printed copies of the materials. Educators were reminded that these support materials are also downloadable online at www.cnmiwaterkids.com.

Two workshops for student teachers and for education majors were arranged at the School of Education at the College of the Northern Marianas, Saipan. The workshops were featuring CNMI Water Kids materials and one additional slide show to spark discussion about the range of key aspects of the importance of fresh water to the community called "Why Do I Need Fresh Water?.

The proposed exploration of future offerings of continuing education classes for teachers was conducted in October 2012. The grantee met with Development Institute Program Manager at Northern Marianas College in this regard. The information provisions for offering courses and rental rates along with generous insight was collected. Educators were given the opportunity for opened ended questions regarding other needs and were asked to indicate their willingness to participate in teacher training courses that may be developed and introduced int the *Critical Water Resources Research, Teaching and Training Needs for the CNMI* assembled by the WERI-CNMI Advisory Council at their future annual meetings.

Findings and Significance

Presentations were scheduled and fulfilled at seven private schools on three islands which represented nearly all schools serving the target audience. At most schools, all sixth grade students and their teachers attended the presentations. In several schools, students at all levels also attended. At one school every student and teacher in the entire school attended in a one-room schoolhouse atmosphere. Two presentations were made at two schools to accommodate class schedules. An unusually high percentage of school principals found time to attend the presentations compared to previous presentations at CNMI public schools and Guam public and private schools.

The following presentations were made during January and February of 2013. Attending from the private schools in the CNMI, were 319 students and 23 educators, and seven principals/vice principals.

		Attendance:		
School	Location	Students	Teachers	Principals
Golden Harvest International	Saipan	13	3	1
Grace Christian Academy-Sai	Saipan	59	3	2
Saipan Community School	Saipan	39	2	1
Saipan Community School (2)	Saipan	21	1	0
Seventh Day Adventist	Saipan	60	6	1
Grace Christian Academy-Tin (2)	Tinian	44	2	1
Grace Christian Academy-Rota	Rota	55	3	1
Eskuelan San Francisco de Borja	Rota	28	3	0
	Totals	319	23	7

Following is a selection of images of the materials presented and photographs from the presentation in the schools and the community. *Figures 1-13 follow.*

Figure1. Website home page www.cnmiwaterkids.com.

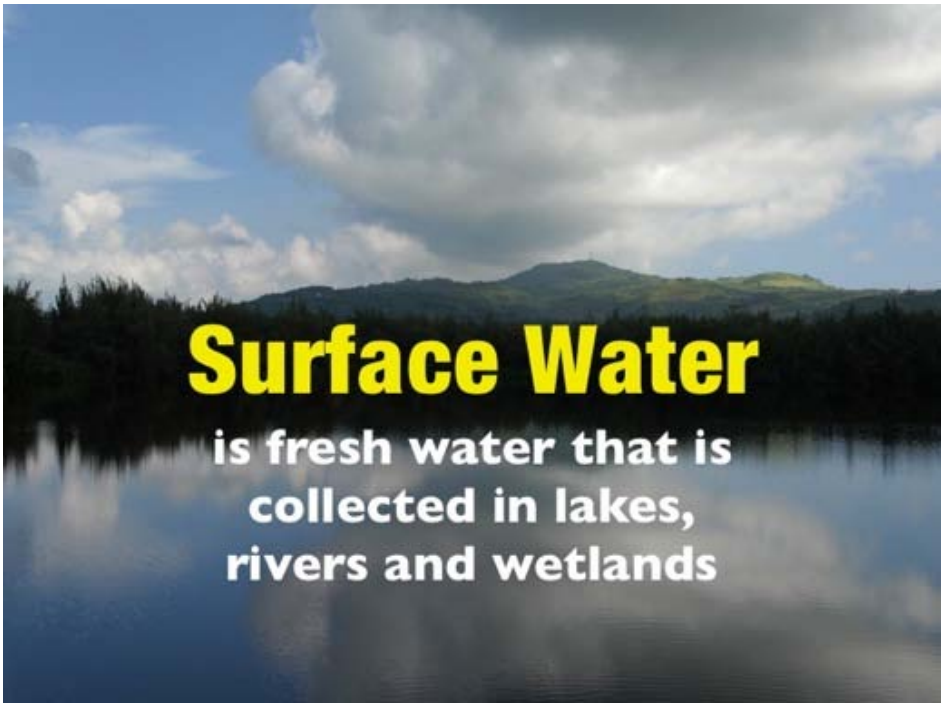


Figure 2. Surface Water slide featuring Lake Susupe, Saipan.

Figure 3. Selection of slides from the "CNMI Water Kids" presentation relating basics of fresh water and how young people can participate in conserving and protecting this natural resource.

Figure 4. Eskuelan San Francisco de Borja Catholic School, Rota.

Figure 5. Eskuelan San Francisco de Borja Catholic School, Rota, presentation in cafeteria by Ann Card.

Figure 6. Golden Harvest International School, Saipan, group photo.

Figure 7. Golden Harvest International School, Saipan, group photo, mural in progress.

Figure 8. Grace Christian Academy-Saipan, the largest private school on Saipan.

Figure 9. Grace Christian Academy-Saipan, presentation in multi-use sanctuary.

Figure 10. Eskuelan San Francisco de Borja Catholic School, Rota, students.

Figure 11. Eskuelan San Francisco de Borja Catholic School, Rota, students with Jennifer Berry.

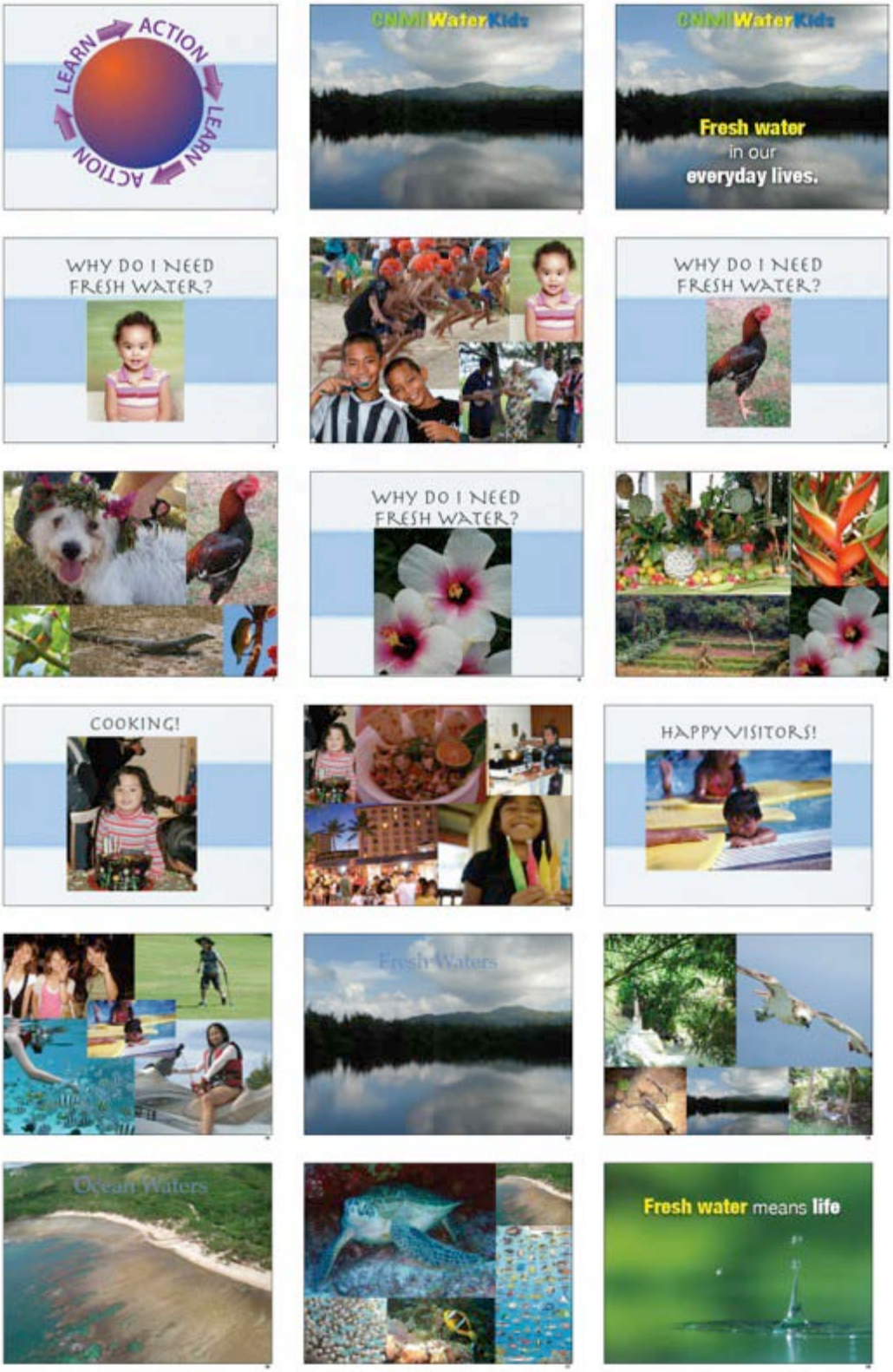
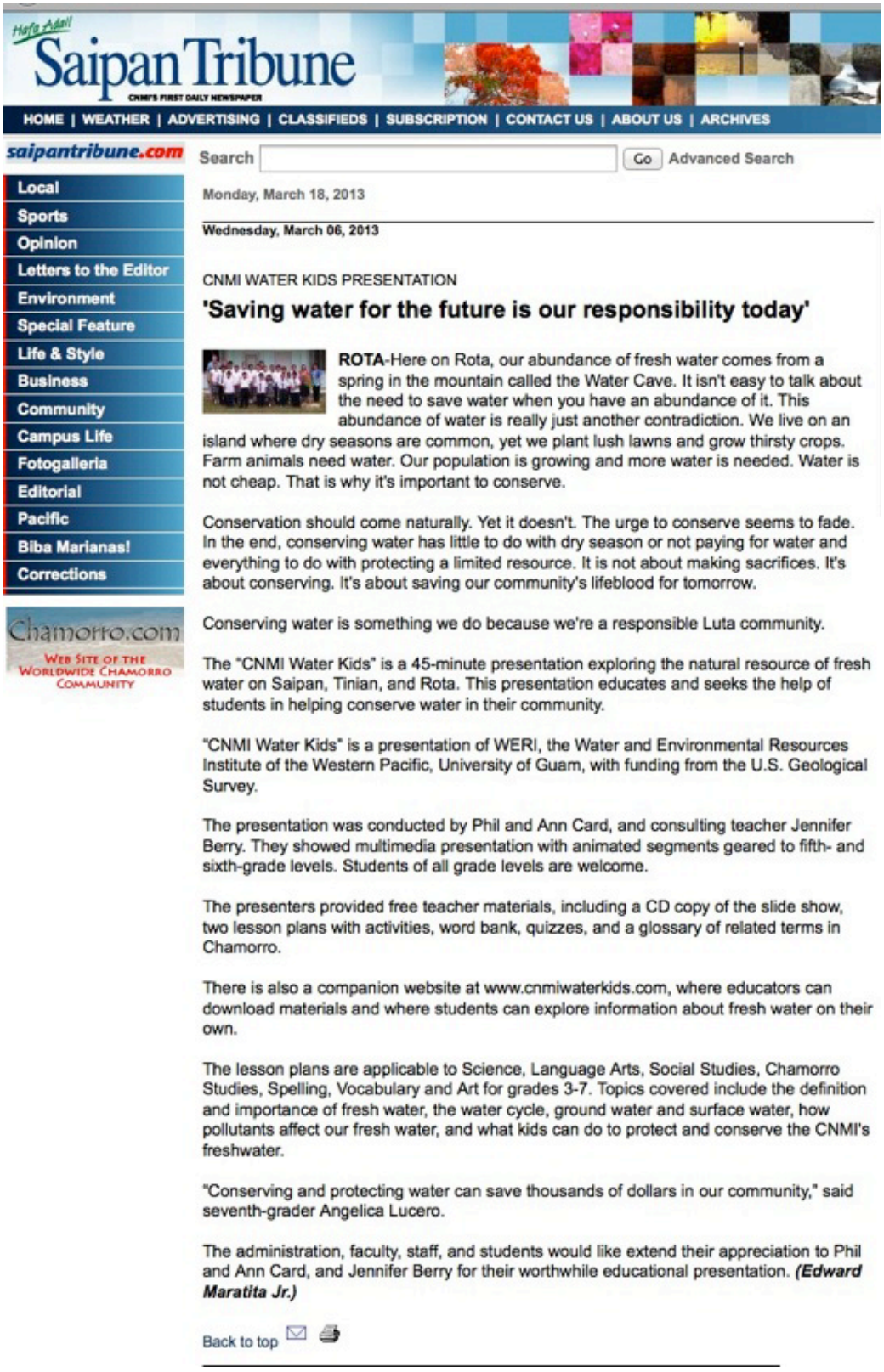


Figure 12. Slide show prepared for Northern Marianas College students in School of Education to demonstrate the basic definition of fresh water and its importance.



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Web Site of the Worldwide Chamorro Community

Monday, March 18, 2013

Wednesday, March 06, 2013

CNMI WATER KIDS PRESENTATION

'Saving water for the future is our responsibility today'

ROTA-Here on Rota, our abundance of fresh water comes from a spring in the mountain called the Water Cave. It isn't easy to talk about the need to save water when you have an abundance of it. This abundance of water is really just another contradiction. We live on an island where dry seasons are common, yet we plant lush lawns and grow thirsty crops. Farm animals need water. Our population is growing and more water is needed. Water is not cheap. That is why it's important to conserve.

Conservation should come naturally. Yet it doesn't. The urge to conserve seems to fade. In the end, conserving water has little to do with dry season or not paying for water and everything to do with protecting a limited resource. It is not about making sacrifices. It's about conserving. It's about saving our community's lifeblood for tomorrow.

Conserving water is something we do because we're a responsible Luta community.

The "CNMI Water Kids" is a 45-minute presentation exploring the natural resource of fresh water on Saipan, Tinian, and Rota. This presentation educates and seeks the help of students in helping conserve water in their community.

"CNMI Water Kids" is a presentation of WERI, the Water and Environmental Resources Institute of the Western Pacific, University of Guam, with funding from the U.S. Geological Survey.

The presentation was conducted by Phil and Ann Card, and consulting teacher Jennifer Berry. They showed multimedia presentation with animated segments geared to fifth- and sixth-grade levels. Students of all grade levels are welcome.

The presenters provided free teacher materials, including a CD copy of the slide show, two lesson plans with activities, word bank, quizzes, and a glossary of related terms in Chamorro.

There is also a companion website at www.cnmiwaterkids.com, where educators can download materials and where students can explore information about fresh water on their own.

The lesson plans are applicable to Science, Language Arts, Social Studies, Chamorro Studies, Spelling, Vocabulary and Art for grades 3-7. Topics covered include the definition and importance of fresh water, the water cycle, ground water and surface water, how pollutants affect our fresh water, and what kids can do to protect and conserve the CNMI's freshwater.

"Conserving and protecting water can save thousands of dollars in our community," said seventh-grader Angelica Lucero.

The administration, faculty, staff, and students would like extend their appreciation to Phil and Ann Card, and Jennifer Berry for their worthwhile educational presentation. ***(Edward Maratita Jr.)***

Back to top

Figure 13. Newspaper story and featured group photo from the *Saipan Tribune*, March 18, 2013, featuring the "CNMI Water Kids" presentations on Rota.

Identifying Sustainable Water Storage Infrastructure for Atoll Island Communities

Basic Information

Title:	Identifying Sustainable Water Storage Infrastructure for Atoll Island Communities
Project Number:	2012GU228B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	N/A
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Hydrology, Models
Descriptors:	Atoll islands, groundwater management, Federated States of Micronesia
Principal Investigators:	John Jenson

Publication

1. Bailey, Ryan T., John W. Jenson, and Danko Taboro¨i, 2013, Estimating the Freshwater Lens Thickness of Atoll Islands in the Federated States of Micronesia: Hydrogeology Journal, 21(2), 441-457. doi: 10.1007/s10040-012-0923-6.

PROJECT SYNOPSIS REPORT

Project Title: Identifying sustainable water storage infrastructure for atoll island communities

Problem and Research Objectives

Water shortages are a persistent concern for residents of atoll islands. Under normal conditions, demand is met by rooftop rain catchment, but prolonged droughts can exhaust storage, leaving residents dependent on groundwater or imported water. The objective of this project was a comprehensive water resources assessment for atoll island communities for water resource managers in the FSM.

Methodology

This was accomplished in two phases: First, by applying state-of-the-art modeling results and field-collected information to obtain available water supply volumes for atoll island communities. Second, providing results of the research in the form of user-friendly spreadsheet management tools through a workshop conducted at the FSM Advisory Council meeting in Yap, FSM in October 2012. The latter objective also served to cultivate an ongoing technical support relationship between the authors and end-users so that there will be a continuing dialogue to support continued successful use and application of research results to water resource management in the FSM.

The first phase consisted of combining the developed groundwater management tool with a rain catchment system storage calculator, so that total daily water supply can be calculated for a given atoll island community. Rain catchment volumes were calculated using daily water balance calculations and a knowledge of the available water storage tanks and guttered roof area. A spreadsheet tool was developed that enables the user to input island surface geometry and rain catchment system dimensions and, with daily rainfall data gathered from weather stations, calculates and plots daily water volumes during the targeted time period. For the second phase, WERI instructors used printed handouts ("Atoll Island Water Storage Calculator" handout) and a supporting PowerPoint presentation to deliver lectures on the basic aspects of atoll hydrology and conducted laboratory-type training on the use of the new spreadsheet.

Principal Findings and Significance

The use of the spreadsheet tool can help water resource managers plan for upcoming drought periods and facilitate the implementation of sustainable water management practices. The training from the workshop will enable FSM water resources managers and planners to make more reliable policies and plans to support or build sustainable communities with good quality of life on the atoll islands of the FSM. Improving water resources availability and sustainability on small island communities will promote economic and social stability, as well as preserving the preferred way of life for many current and future residents of the FSM. Participation of island science educators in the training provides a basis for improved long-term education of students as well as the public at large on island hydrology and water resources management in general, and atoll island hydrology and water management in particular.

Water System Leak Detection Training for Pohnpei Utilities Corporation (PUC), the Federated States of Micronesia

Basic Information

Title:	Water System Leak Detection Training for Pohnpei Utilities Corporation (PUC), the Federated States of Micronesia
Project Number:	2012GU229B
Start Date:	3/1/2012
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	N/A
Research Category:	Not Applicable
Focus Category:	Education, Water Supply, Management and Planning
Descriptors:	Water resources, Training, Education, Operation and Maintenance
Principal Investigators:	Shahram Khosrowpanah

Publications

There are no publications.

PROJECT SYNOPSIS REPORT

Project Title: Water System Leak detection Training for Pohnpei Utilities Corporation (PUC), the Federated States of Micronesia

Problem and Research Objectives

Water system leakage is a common problem for every utility agency. It reduces the performance of the system and causes financial losses for utilities. A healthy water system can have up to 20% leakage. This is depending up on the age of the system components such as pipes, valves, meters, and the system operation. This problem is more serious in the Western Pacific. The development of modern water distribution systems for most of the islands in this area started in 1970. Since then the systems have been upgraded through a series of US sponsored capital improvements projects. However, system leakage for some of these islands is as high as 60%. Utility agencies are suffering from lost revenues and are not able to provide 24- hour water service to their customers. Leak detection is one of the most cost effective and efficient ways to reduce non-revenue water. In fact, a leak detection program should be the highest priority with each utility agency. It is cost effective, and has the immediate results of increasing the system performance. In response to these unique circumstances, a special training program has been designed for FSM. The training concentrated on water system leak detection for Pohnpei Utility Corporations (PUC). The specific objective of this training was to increase the technical understanding of: 1) system leakage theory, 2) application of leak detection, 3) how to manage the leakage, and 4) use state of the art leak detection equipment. This specific training was requested by the Pohnpei State as part of the WERI advisory council meeting held in October 2011.

Methodology

The training project consisted of a one week long workshop that provided an understanding the leak detection theory and how to find leaks and fix them. As can be seen from the schedule below (Table 1), the training provided a mix of classroom, laboratory and field site instruction and hands-on activities. The Pohnpei Utility Corporations (PUC) provided the required classroom and shop space to carry out the training.

The instructor who led the training was Mr. Tom Ruppenthal, field services/training from Utility Services Associates. This company is based in Washington and they specialize in leak detection.

Upon completion of the workshop the attendees had a much better understanding of key operation and maintenance activities required to sustain functioning water distribution and wastewater collection systems with special emphasis on pump repairs and operation.

Table 1. Training activities

A. Classroom Training covering the following topics (Approximately 1.5 day):

1. Introduction to a leak detection program / theory.
2. Explanation of how leak sounds originate. Discussion of leak sound transmission through different types and sized of pipe
3. Explanation of "Acoustic Leak Survey" & each type of survey including permanent monitoring. Introduction to survey tools/ equipment and the benefits of each.
4. Leak sounds exercise – (class did very well with this test)
5. Discussions and recommendations of paperwork / reporting practices that may be utilized in the field. Distributed field forms to attendees for consideration
6. Hands on experience to cover the operation of the LD-12 leak detection
7. Started discussion on correlation theory and explained how a correlator locates water leaks
8. Discussed three rules of correlation, best contacting practices, and correlation formula that enables the correlator to measure time delay

B. Field Training covering the following topics (Approximately 3.5 days):

1. Demonstration of equipment
2. Hands on training and field practice on pinpointing leaks, estimating leakage, reporting, and review

C. Equipment:

The following equipment was used during the training:

1. Subsurface Leak Detection LC2500 leak noise correlator
2. Fluid Conservation System S-30 leak noise surveyor
3. Subsurface Leak Detection LD-15 leak noise detector
4. Subsurface Leak Detection LD-12 leak noise detector
5. Subsurface Instruments PL-2000 pipeline locator
6. Subsurface Instruments ML1 Ferrous locator
7. Probe rods
8. Audio and visual media presentations

Principal Findings and Significance

A total of eleven (11) people working at the Pohnpei Utility Corporations (PUC) completed the training. The training covered leak detection theory, and how to determine when a leaky survey is required, economic benefits of a leak detection survey, how to incorporate a leak detection survey and/or permanent leak detection crew for your water facility, how to become familiar with various sounds created by leaks and type of leaks encountered, types of leak detection surveys and proper record keeping, get familiar with various leak detection equipment and techniques, and field demonstration and actual leak detection scenarios and exercises.

The net result of this training is increased knowledge of PUC personnel on water conservation and leak detection technology. The benefits will be a reduction of non-revenue water and better management of one of Pohnpei island's most valuable resources, its water. As always our goal will be to help provide the local government with on-island capabilities to maintain water supplies that that can provide safe drinking water for the entire island on a 24-hour basis. After

the training Mr. Tom Ruppenthal, lead instructor, submitted his observations and recommendations for future improvement of PUC water system that is attached.

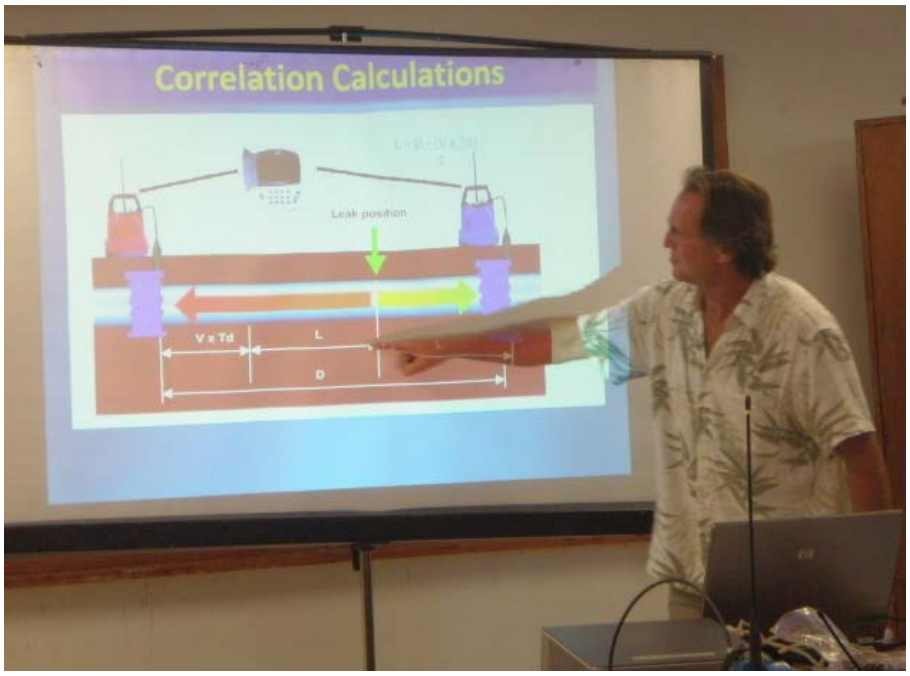

Figure 1. Class room lecture presentation

Figure 2. Students learning in class

Figure 3. Student participation

Figure 4. Student at field

Figure 5. Field work

Figure 6. Students Completed the Training

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	5	0	0	0	5
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	7	0	0	0	7

Notable Awards and Achievements

For the fourth year in a row, WERI conducted the highly popular Groundwater Resources Management Training Course specifically developed for the inhabitants of atoll islands in the FSM. This year the 104-B-sponsored course was done in conjunction with the WERI-FSM Advisory Committee meeting held in Yap State in early October. Participants were trained in the use of a high-resolution computer model of an idealized atoll aquifer to predict the sustainable management of their groundwater resources under various climatic scenarios. As it has in the past, the workshop attracted island leaders and government officials and was very well received by all. WERI has committed to offering additional workshops in conjunction with the next advisory meeting. The model is now being expanded to incorporate rain catchment use and storage, in addition to groundwater.

WERI faculty continues to engage both graduate and undergraduate students in their research activities. During this past year we are pleased to announce that two WERI-sponsored students, Ms. Christine Simard (spring 2012) and Ms. Vivianna Bendixson have graduated from the Environmental Science MS Program (Spring 2013). Ms. Simard s thesis, Salinity Trends in the Northern Guam Lens Aquifer. Ms. Simard s thesis won the University of Guam President s Award for the outstanding graduate thesis of 2012and in June 2012, she presented her results to other carbonate island researchers at the 16th Geology Conference at the Gerace Research Center in San Salvador, Bahamas,. The project has recently been selected by the National Institutes for Water Resources Research (NIWWR) as this year s winner of its annual National Impact Award. Lead principal investigator, Dr. John Jenson, and Ms. Simard have been invited to attend the 2013 meeting of the Universities Council on Water Resources and NIWWR at Lake Tahoe in June to accept the award and deliver a presentation on the project. Technical reports and manuscripts for the professional literature are underway.

Ms. Bendixson is first WERI-sponsored student to earn an MS degree through the new Professional Track of the University of Guam's Graduate Environmental Science Program. The professional track option allows students to earn a degree for the kind of work that they can expect to do as a professional employee for an engineering firm or government agency. Ms. Simard built a comprehensive database for the Northern Guam Lens Aquifer, from which Guam gets 80% of its drinking water. Construction of the database required locating and examining over 500 historical drilling logs and related records on aquifer geology and hydrology. The database is interfaced with state-of-the-art GIS mapping and graphic visualization tools, and directly supported the construction of a map of the aquifer basement rock, which is the single most important tool for successful exploration. It is also essential for the construction of accurate numerical models, including the new numerical model of the aquifer constructed by the USGS in collaboration. The database will henceforth be maintained and kept up to date at WERI as a permanent major tool for all water resource developers, managers, regulators, and researchers on Guam.

Publications from Prior Years

1. 2009GU162B ("Influence of Stormwater and Wastewater Discharges on the Distribution and Abundance of Heavy Metals in Sediments from Saipan Lagoon") - Articles in Refereed Scientific Journals - Denton, Gary R.W., Carmen Kautz, John Starmer, 2013, Influence of Stormwater Discharges, Inappropriate Waste Disposal Practices and World War II on the Distribution and Abundance of Heavy Metals in Saipan Lagoon, Saipan, Commonwealth of the Northern Mariana Islands, Marine Pollution Bulletin, in press.
2. 2007GU95B ("Mercury Contamination in Garapan Lagoon, Saipan: An Evaluation of Potential Drainage Pathways and Impact on Fisheries Resources ") - Articles in Refereed Scientific Journals - Morrison, R. John, Gary R.W. Denton, U. Bale Tamata, Julien Grignon, 2013, Anthropogenic Biogeochemical Impacts on Coral Reefs in the Pacific Islands An Overview, Deep-Sea Research II, in press.
3. 2008GU140B ("Watershed Management for Pohnpei Island in the Federated States of Micronesia") - Conference Proceedings - Sh. Khosrowpanah, L. Heitz, 2012, Safe Drinking Water: Challenging issue for Tropical Islands in the Western Pacific, Proceedings of XII International Symposium on Environmental Geotechnology, Energy and Global Sustainable Development , International Society for Environmental Geotechnology (USEG), Los Angeles, California, pp 345-353.
4. 2011GU200B ("Environmental Impact of FUDS and Brownfields Sites in Watersheds on the Eastern Side of Saipan. Phase 1: Contaminant Analysis of Soil and Sediments") - Other Publications - Denton, Gary R.W., John A. Starmer, 2012, Abstract, Formerly Used Defense Sites (FUDS) on Saipan: Evaluation of Potential Ecological and Human Health Risks Associated with Heavy Metal Enrichment in Adjacent Soils and Sediments, Abstract, Asia Pacific Academy of Science, Education, and Environmental Management General Meeting, November 13-14, 2012, American Memorial Park Auditorium, Saipan.
5. 1999GUC-09 ("Island Karst Hydrology of Guam and its Incorporation into a General Carbonate Island Karst Model") - Articles in Refereed Scientific Journals - Rotzoll, Kolja., Stephen B. Gingerich, John W. Jenson and Aly I. El-Kadi, 2013, Estimating Hydraulic Properties from Tidal Attenuation in the Northern Guam Lens Aquifer, Territory of Guam, USA, Hydrogeology Journal 21(3): 643-654.
6. 1999GUC-09 ("Island Karst Hydrology of Guam and its Incorporation into a General Carbonate Island Karst Model.") - Articles in Refereed Scientific Journals - Taboro¨i, Danko, John W. Jenson, and John E. Mylroie, 2013, Field Observations of Coastal Discharge from an Uplifted Carbonate Island Aquifer, Northern Guam, Mariana Islands: A Descriptive Geomorphic and Hydrogeologic Perspective: Journal of Coastal Research, 18 p., on-line: DOI: 10.2112/JCOASTRES-D-12-00054.1
7. 2007GU95B ("Mercury Contamination in Garapan Lagoon, Saipan: An Evaluation of Potential Drainage Pathways and Impact on Fisheries Resources ") - Other Publications - Denton, Gary R.W., 2012, Tracking Down an Unusual Source of Mercury Enrichment in Fish from Saipan Lagoon, Saipan, Commonwealth of the Northern Marianas Island, Abstract, Environmental and Occupational Toxicology (ENOTOX) Workshop sponsored by Mapua Institute of Technology in Collaboration with the Swedish International Development Cooperation Agency (SIDA) and Swedish Chemical Agency (KEMI), 22-24 May, 2012, Linden Suites, Ortigas Center, Pasig City, Metro Manila, Philippines.
8. 2005GU54B ("Heavy Metals in Biotic and Abiotic Components of a Guam Reef Flat Impacted by Leachate from a Municipal Dump") - Other Publications - Denton, Gary R.W., 2012, Solid Waste Disposal on Guam: The Impact of an Unsanitary Landfill on the Heavy Metal Status of Adjacent Aquatic Community Representatives, Abstract, Environmental and Occupational Toxicology (ENOTOX) Workshop sponsored by Mapua Institute of Technology in Collaboration with the Swedish International Development Cooperation Agency (SIDA) and Swedish Chemical Agency (KEMI), 22-24 May, 2012, Linden Suites, Ortigas Center, Pasig City, Metro Manila, Philippines.

9. 1999GUC-09 ("Island Karst Hydrology of Guam and Its Incorporation into a General Carbonate Island Karst Model") - Other Publications - Mylroie, John E., John W. Jenson, Blaz Miklavič and Danko Taboroši, 2012, Surface and Vadose Implications in Karstification of Eogenetic Carbonates, GSA Annual Meeting. Charlotte, North Carolina.
10. 2009GU154B ("Reconstructing the Ancient Rainfall-Drought History of Guam") - Other Publications - Lindzey, K. M., J. W. Partin, T. M. Quinn, J. W. Jenson, C.-C. Shen, J. L. Banner, L. K. and B. F. Hardt, 2012, Decadal-Scale Rainfall Variability in Guam over the Common Era, American Geophysical Union Fall Meeting, Abstracts. San Francisco.
11. 2009GU154B ("Reconstructing the Ancient Rainfall-Drought History of Guam") - Other Publications - Miklavič, Blaž, John E. Mylroie, John W. Jenson, Richard H. Randall, Nataša Zabukovec Logar, Danko Taboroši, 2012, Denudation of eogenetic limestone during the last glacial cycle in a tropical environment. 20th International Karstological School "Classical Karst": Karst forms and processes; 18th to 23rd June, 2012; Karst Research Institute, Postojna, Slovenia.
12. 2009GU154B ("Reconstructing the Ancient Rainfall-Drought History of Guam") - Other Publications - Miklavič, Blaž, John E. Mylroie, John W. Jenson, Richard H. Randall, Jay L. Banner, Judson W. Partin, 2012, Evidence of the sea-level change since MIS 5e on Guam, Tropical West Pacific, NSF Workshop: Sea Level Changes into MIS 5: from observations to predictions, April 10-14, 2012, Palma de Mallorca, Mallorca, Spain.
13. 2010GU174B ("Impact of Urban Runoff, Wastewater Discharges and Past Solid Waste Disposal Practices on Contaminant Profiles in Fish from Saipan Lagoon") - Other Publications - Denton, Gary R.W., Michael S. Trianni, and Michael C. Tenorio, 2011, Abstract, PCB Status of Popular Table Fish from Northern and Central Sections of Saipan Lagoon, Abstract, Asia Pacific Academy of Science, Education, and Environmental Management General Meeting, November 29-30, 2011, American Memorial Park, Auditorium, Saipan.